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Development and Evaluation of Protective Clothing for Rose Farmers

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Abstract

Protective clothing developed for rose flower farmers has been evaluated to improve the working conditions. The requirements of rose farmers were first identified to design protective clothing for farmers working with thorny plants. A fit test was conducted to assess the thermal comfort and protective function against thorn pricking to compare and evaluate the usability of developed experimental clothing with existing working clothes. Based on the survey results of rose farmers' requirements, protective clothing was designed in the form of an apron (which was the most preferred after gloves) with a pattern designed for the production of experimental clothing. For the developed protective clothing, the strap and buckle closure method was selected to open the back of the body as much as possible; in addition, sleeves were made in the attachable form of a half-sleeve to protect the arms from the thorns. The fit test of the developed protective clothing and existing working clothes revealed the temperature and humidity inside the developed protective clothing to be significantly different in the back compared to existing work clothes. In addition to thermal sensations, the subjective humidity sensations were statistically significant different in the developed protective clothing compared to existing work clothes. The subjective protective function for thorn pricking was also found to be satisfactory.

***Key words*:** Protective clothing, Design, Protective apron, Thermal comfort, Rose farmer

I. Introduction

Thorny plants refer to plants with thorns on their branches, such as roses, cacti, cucumbers etc. Among these, roses form a large proportion of the floricultural industry, comprising 30% of Korea's total cut-flower cultivation area and the item cultivated the most after chrysanthemums among cut-flowers (Ministry for Food, Agriculture, Forestry and Fisheries [MIFAFF], 2010). Horticultural roses are normally grown in greenhouses and the work steps are divided into rose cutting and sorting work, regardless of the season. Rose cutting involves cutting rose stems with scissors, holding them in a bundle and moving them to a sorting place. At this time, the worker's hands, arms, shoulders, and chest can be pricked by thorns and wounds on the arms are particularly severe due to the load of a bunch of roses. Rose sorting involves classifying the cut roses into flower types, and mainly involves women. When sorting, the worker's belly and hands are the main parts exposed to thorn pricking. After returning home from work, most rose farmers have to pull out rose thorns with a pin and disinfect the injured part. Therefore, facility horticulture rose cultivators are prone to exposure to thorn pricking, as well as the hot working environment within a greenhouse. Damage due to a hot working environment and

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thorn pricking can reduce the working efficiency and even cause work stress. Therefore, it is essential to wear adequate protective equipment.

Protective clothing is one of the many types of personal protective equipment and its purpose is to protect humans from harmful environments (Yun, 2006). A review of protective clothing-related studies for improving the farm work environment revealed the development of pesticide-proof clothes (Choi & Lee, 2002; Chung & Kim, 1999; Kim, 1983; Shin & Kim, 1999; You, 2006) to have attracted the most attention. Moreover, as cultivation in greenhouses increase sharply, studies of the development of greenhouse working clothes (Myung et al., 1993) and the development of cooling vests (Choi et al., 2005a) to protect workers from hot and humid environments within the workplace have been conducted. The development of agricultural working clothes for workers dealing with thorns focused mainly on the production of protective gloves for rose farmers (Chae et al., 2012).

Gloves or arm protectors for preventing rose thorn pricking have been developed and are commercially available in foreign countries. Gloves are designed ergonomically using natural leather and new materials, and have been developed to protect the hands, fingers, joints, and arms, as well as provide the optimal behavior flexibility (“Arm protectors”, 2011; “Classic gardeners'”, 2014; “Ladies gray”, 2016; “Womens ultimate”, 2016). On the other hand, Korean farmers do not often purchase goods for thorn workers sold in foreign countries because the overseas sales of these goods are not permitted and they are too expensive for farmers on a low income.

Although rose farmers recognize the need to protect their body from thorn pricking while working, there is no adequate protective equipment on the market. Currently, the upper body is protected from thorn pricking using a general-purpose apron or jumper, and the lower body is protected with thick jean pants. The hands, which are the most severely pricked by thorns, are protected by wearing kitchen rubber gloves on top of general cotton gloves or non-permeable film type coating gloves. Although a thorn pricking preventive effect can be expected by covering the skin likely to be damaged with a jumper and jeans, the reduced thermal comfort in a hot and humid greenhouse can increase the level of work fatigue and reduce the work efficiency. Despite this, the actual conditions of thorn pricking have not been reported nor has a demand survey been performed or protective equipment been developed.

Therefore, in this study, protective clothing that improves the work load on thermal stress and exposure of thorn pricking was developed for workers dealing with plants with thorns. The objective and subjective thermal comfort were evaluated to compare the differences between the developed protective clothing and existing working clothes. The dissemination of developed thorn protective clothing to farmers will make the farming environment much more convenient and healthy.

II. Research Methods

1. Demand Survey for Farmers

For data collection, through snowball sampling of non-probability sampling, a survey was conducted targeting 35 farmers (19 males, 16 females) with the same characteristics of facility horticulture for rose. The questionnaire consisted of the participant's age, gender, total years farming, whether pricked by thorns while working, body parts pricked by thorns, and the preferred form of thorn protective clothing. Respondents were asked to answer yes or no whether they had been pricked by thorns during work. The survey asked to choose all body parts pricked often among the feet, legs, shoulders, abdomen, chest, arm, and hand. The survey also required the subjects to select all items that they considered to be thorn protective clothing. Pants, arm protector, vest, apron and gloves were presented as a type of protective clothing with a multiple-choice question on the questionnaire.

Of those surveyed, those aged in their 40s and 50s were the most frequent, 34.3% and 31.4%, respectively, and 85.7% of respondents had been engaged in rose cultivation for more than 5 years. The basic statistics, such as frequency, mean, percentage, etc., of the data collected were calculated using the SPSS Windows 14.0 statistical program.

2. Design and Making of Experimental Clothing

Based on an identification of the actual conditions on thorn pricking and the demand survey for rose farmers, the materials were selected by considering the protective function for thorn pricking and thermal comfort aspect and designed protective clothing. Currently, in Korea, there are no special protective clothing-related evaluation standards, such as thorn pricking prevention (Hong, 2004), and「보호구성능검정 규정」[「Regulation on Protective Equipment Performance Testing」] (2004) prescribes that the piercing strength of protective clothing be more than one level (>5N). In this study, materials with more than six levels (>250N), the highest piercing strength of protective clothing standards for organic compounds, were selected. <Table 1> lists the property evaluation results of the materials used in experimental clothing. An evaluation of the lining for pockets was not performed because it was not intended for protective use. The design of protective clothing was constructed to select the most preferred form in the demand survey and satisfy both the protective function for thorn pricking and thermal comfort. The pattern was designed and test products were produced based on this.

3. Fit Testing

1) Subjects

The subjects were 10 adult females whose body dimensions were included within the scope of medium size (height 145-175cm, chest 82-89cm, hip 88-95cm) as 'Adult top and bottom connecting clothes' presented in the Sizing systems for female adult's garments by Korean Agency for Technology and Standards ([KATS], 2009). The purpose and contents of the experiment were explained, and voluntary consent for participation in the study was obtained. The body size of the subjects was measured in the same way as the method presented in the 5th body measurement survey (KATS, 2005). The age, height, weight, body surface area, and body weight index of the subjects was 31.7±8.4years, 160.5±5.3cm, 49.4±4.5kg, 1.50±0.1m^3, and 19.2±1.6kg/m^3, respectively.

2) Experiment Design

To compare the protective clothing developed in this study with the existing working clothes, the subjects were asked to wear kitchen rubber gloves on top of cotton gloves with existing working clothes, such as a general purpose jumper, a similar type of working clothes worn by current farmers while cutting roses. They were also asked to wear gloves developed for rose farmers by Chae et al. (2012) with the experimental garment. <Table 2> lists the combination of experimental clothing and sizes except for gloves. The subjects were asked to wear their normal under garments, short-sleeve T-shirt, long pants, socks, and shoes inside experimental clothing.

3) Evaluation Criteria

The objective and subjective evaluation for thermal comfort, subjective satisfaction for protective function for thorn pricking were carried out for fit testing (Table 3). For objective thermal comfort, the skin temperature, temperature and humidity inside the clothing, heart rate, and subjective sensations were measured in an artificial climate chamber. For the skin temperature, 4 body parts (belly, upper arm, back of the hand, and

Table 1. Fabric characteristics for experimental protective clothing

Characteristics	Fabric	
	Outshell, analysis methods	Lining (for pocket)
Fabric content	Cotton 65%, Linen 35%, Polyurethane laminate	Mesh
Weave structure	Plain	
Thickness	0.50mm	
Weight	398.0g/m^3 (Sample: 597.0g)	
Piercing strength	307.5 N, KS K 0350 ball bursting methods (Korean Agency for Technology and Standards [KATS], 2011)	

thigh) were measured using a portable skin temperature measuring apparatus (LT 8A, Gram Corp., Japan). For the temperature and humidity inside the clothing, 2 body parts (chest, back) were measured using a portable automatic temperature and humidity memory unit (Thermo Recorder RS-10, Tabai Espec Corp., Japan). The heart rate was measured using a digital heart rate measuring apparatus (Polar Sports Tester, Polar Electro INC, Finland). For the subjective thermal comfort, thermal sensation, humidity sensation and comfortable sensation were measured using an 11 level scale from Winakor (1982). The protective function for thorn pricking was assessed as the satisfaction with the protective function for the shoulders, chest, arms, and hands, and ranged from 'Very dissatisfied' 1 point to 'Very satisfied' 5 points; a positive evaluation was closer to 5 points.

4) Experimental Procedures

The conditions for growing facility horticulture for roses were 23-30 in day (Cheong et al., 2012). In this study, the work environment for facility horticulture rose cultivation was reproduced in an artificial climate chamber and the experimental environment was set to 25±0.5 and 50±10%RH (Fig. 1).

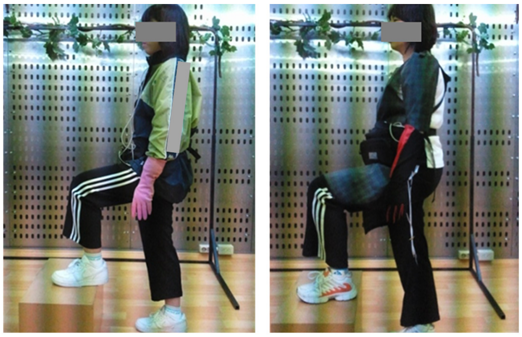
The experimental procedures were conducted by dividing the experiments into an artificial climate chamber experiment and rose cutting work reproduction experiment. Through the artificial climate chamber experiment, the objective and subjective thermal comfort measurement data was obtained, and the subjective measurement data for the satisfaction evaluation of protection from the thorns was obtained from a rose cutting work reproduction experiment. For the artificial climate chamber experiment, one subject was exposed to the experiment by wearing two types of experimental clothing. The wearing order of the existing work clothes and the developed protective clothing was chosen randomly. After the anthropometric measurements, the following were attached to the subjects: thermo-recorder inside the clothing, skin temperature monitor on the belly, upper arm, upper leg, and back of the hand, and heart rate monitor on the chest. The subjects then entered the artificial climate chamber and were allowed to rest for 10 minutes. They then performed the step exercises for 10 minutes (step procedure). According to Lee (1989), 30cm in height, which was the suggested reference value of Korean Step Test, was applied to the step and a 50steps/min a metronome speed was set. After 5 minutes break (safety gap), they performed the step exercises again for 10 minutes and took a rest for 5 minutes (safety gap). This process was repeated for another experimental garment with an interval of 30 minutes. Through the preliminary test,

Table 2. Fit testing experiment design

	Existing clothing	Developed clothing
Type	· General purpose jumper · Kitchen rubber gloves, cotton gloves	· Experimental apron · Experimental gloves developed by preceding research
Material (%)	· Polyester: 100	· Cotton: 65 · Linen: 35
Size (cm)	· Chest circumference: 93 · Sleeve length: 60 · Total length: 57	· Waist breadth: 62 · Sleeve length: 32 · Total length: 92
Common: Underwear, T-shirt, Pants, Socks, Running shoes		

Table 3. Fit testing experimental items

Testing		Part of measurement	Measuring apparatus
Objective thermal comfort	Temperature and humidity inside the clothing	Chest, Back	Thermo recorder (Thermo Recorder RS-10, Tabai Espec Corp., Japan)
	Skin temperature	Belly, Upper arm, Upper leg, Back of the hand	Skin temperature monitor (LT 8A, Gram Corp., Japan)
	Heart rate	Heart rate monitor (Polar Sports Tester, Polar Electro INC, Finland)	
Subjective sensation	Thermal sensation	11 level scale from Winakor (1982)	
	Humidity sensation		
	Thermal comfort		
Satisfaction with the protective function		5 point Likert scale	



(a) Current work wear (b) Developed work wear

Fig. 1. Experiment in the artificial climate chamber.

the time for wearing the 2nd experimental clothing and taking a rest was set to 30 minutes.

When the artificial climate chamber experiments were complete, the subjects were asked to reproduce rose cutting work and conduct the subjective evaluation for protective function for thorn pricking of the developed protective clothing. The reproduction of the rose cutting work was carried out twice in Step 1 (pick up rose stems on the table one by one and put it on the arm of the opposite side), Step 2 (hold a bundle of 50 roses and place it on the floor 1m away and then place it back on the table), and the subject was then asked to write down the results of a subjective assessment.

5) Data Analysis

To compare the difference between the existing working clothes and developed clothing, the mean and standard deviation of the data obtained through the experiment were calculated using SPSS PC (ver. 14.0), and the data was analyzed using a paired *t*-test.

III. Results and Discussion

1. Results of Demand Survey Targeting Farmers

According to the survey targeting a horticulture rose growing facility, 88.6% of respondents answered that they were pricked by thorns while working. The parts pricked most often by thorns were in the order of hands (87.5%), arms (71.9%), chest (21.9%), abdomen, shoulder, leg, and feet (Fig. 2). The hands and arms were the most severely pricked by thorns because they are used in all working steps. In the interview with farmers, they answered that they selected a jumper and jeans as the working clothes because a jumper and jeans prevent them from being pricked by thorns better than the other clothes. On the other hand, they complained of discomfort while working in a greenhouse because of the low thermal comfort in contrast to the thorn pricking effect. 91.2% of respondents answered that the new protective clothing for protection from thorns is essential and gloves (90.0%) and an apron (53.3%) were the most preferred form of protective clothing (Fig. 3).

2. Design of Experimental Clothing

By considering the aspects of the objective and subjective thermal comfort and the protective function for thorn pricking based on the results of the demand survey targeting farmers, the experimental clothing was made by selecting protective clothing materials, sketch and pattern design (Fig. 4)–(Fig. 6). Although an apron was the second preferred in the survey for farmers, this study selected it for the type of protective clothing because the gloves for thorn pricking were already developed by Chae et al. (2012). To reduce the burden of the sequence in a greenhouse, the experim-

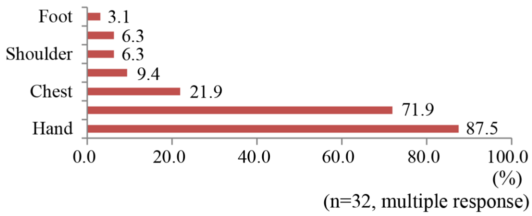


Fig. 2. Body parts pricked by thorns.

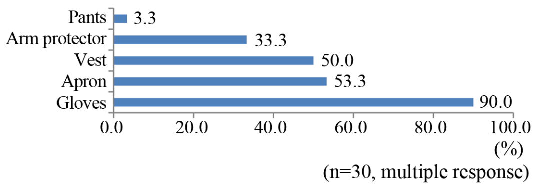


Fig. 3. Preferred form of thorn protective clothing.

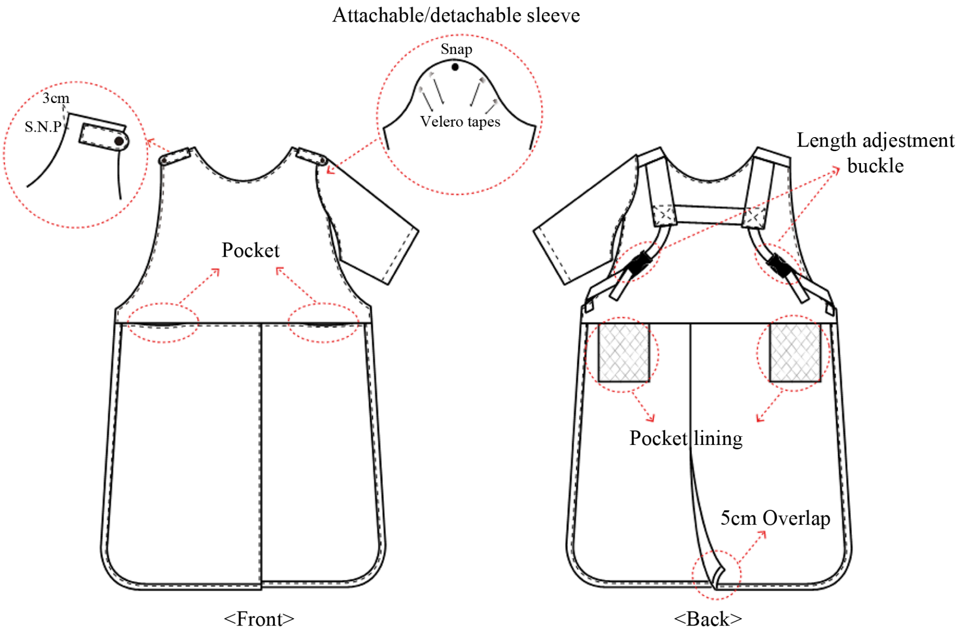


Fig. 4. Flat sketches of the experimental clothing.

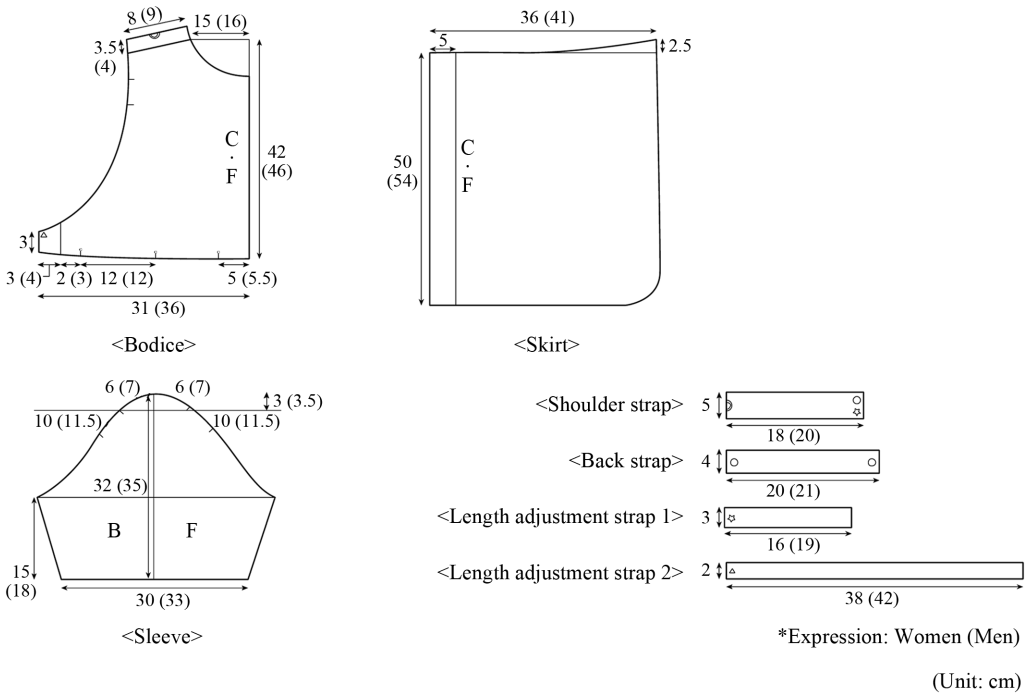


Fig. 5. Pattern for experimental clothing.

<Front> <Back & sleeve>

Fig. 6. Experimental clothing prototype.

ental apron selected had a strap as the closure method to open the back of the body as much as possible and a buckle was used to adjust the length. The garment was made in the form of combining one sleeve to protect the upper arm holding a bundle of roses while cutting the roses. To form the sleeve on the left or right depending on the position of the hand used mainly by the worker, the sleeve is attached by a button on the shoulder and could be fixed stably to the bodice by attaching 2 round Velcro tapes in the front armhole part. The apron comes down to the knees and a cutting line was made in the skirt waist part, where the top and bottom are separated to allow lower limb action and the center line of the bottom part was cut and separated to make an approximate 5cm overlap. The bodice basic pattern and sleeve basic pattern of the apron were designed with reference to the basic pattern making method reported by Jeong and Chung (2008), and the size of the experimental clothing was designed by considering the basic physical dimensions of ‘top and bottom connecting clothes’ of Men M size (height 157-170cm, chest size 85-93cm, waist size 70-80cm) and Women M size (height 145-175cm, bust 82-89cm, hip circumference 88-95cm) in the KS adult clothing size standard system (KATA, 2009). The rear shoulder line was moved 3.5cm from the shoulder center line to the back to prevent the rear closure end from leaning forward. The sleeve was 32cm long and a half-sleeve came down to the elbow while being worn and the armhole shape for the right and left sides were the same based on the sleeve center line to ensure that it can be attached to the other side of the arm after being detached. The armhole line of the bodice and sleeve was designed to be overlapped by a 3cm width and 12cm length from the shoulder point, which can prevent pricking with thorns through the gap of the separated sleeve. The aprons separated into two sheets were overlapped by 5cm according to the center line. Based on the designed pattern, the experimental clothing was made by applying the polyurethane laminate coating material of cotton 65.0% and linen 35.0%.

3. Results of the Objective Thermal Comfort Evaluation

Through an evaluation of human fit testing, the temperature and humidity inside the clothing, skin temperature, heart rate for the existing working clothes (Jacket, cotton glove+rubber gloves of general purpose), and developed protective clothing were compared and evaluated (Table 4). The temperature inside the clothing did not show a significant difference in the chest part but the temperature inside the clothing of the back part showed significant difference: the existing working clothes and the developed protective clothing showed a mean value of 35.2 and 31.6, respectively, after 40 minutes of exposure. Similar to the temperature inside the clothing, the humidity inside the clothing showed a significant difference in the back part but not in the chest part. The existing clothes and developed protective clothing showed a mean value of 57.6%RH and 44.5%RH, respectively, showing a significant difference. The skin temperature did not show a significant difference in the belly, upper arm, back of the hand, thigh of both existing working clothes, and developed protective clothing. According to Hwang et al. (2007), among the body parts cooled, the heart rate showed an increase when the belly was cooled. In this study, the heart rate did not show a significant difference between the existing clothes and the new clothing because the new design did not affect the temperature of the chest and abdomen.

4. Evaluation of the Subjective Thermal Comfort

The subjective thermal comfort was compared and

Table 4. Physiological response during the experiment (n=10)

Items		Existing clothing		New clothing		*t*-value
		Mean	S.D.	Mean	S.D.	
Temperature inside clothing (°C)	Chest	32.3	1.04	32.7	1.88	−.570
	Back	35.2	4.39	31.6	1.17	2.531*
Humidity inside clothing (%RH)	Chest	65.1	15.10	65.9	16.58	−.109
	Back	57.6	10.86	44.5	11.30	2.640*
Skin temperature (°C)	Belly	34.1	1.17	33.5	.98	1.007
	Upper arm	33.0	.63	32.9	.99	.457
	Upper leg	32.7	2.00	33.9	1.85	−1.289
	Back of the hand	34.6	.22	34.6	.71	.240
Heart rate (bpm)		105.2	8.14	101.0	11.99	.923

$^*p<.05$

Table 5. Subjective sensation during the experiment (n=10)

Items	Existing protective clothes		Experimental apron		*t*-value
	Mean	S.D.	Mean	S.D.	
Thermal sensation	2.7	.41	1.6	.55	4.650**
Humidity sensation	2.5	.84	1.6	.38	2.599*
Thermal comfort	.6	1.37	−1.2	1.36	2.567*

$^*p<.05$, $^{**}p<.001$
Thermal sensation: Cold (−5)-Hot (5), Humidity sensation: Dry (−5)-Wet (5), Thermal comfort: Comfortable (−5)-Uncomfortable (5)

evaluated during the fitting experiment in the artificial climate chamber. The results showed that while wearing the developed protective clothing, the thermal sensation, humidity sensation and comfortable sensation were significant better than when wearing the existing working clothes (Table 5). Choi et al. (2002) reported that the subjective sensation felt by workers after working in a greenhouse was 'Hot, very humid and slightly uncomfortable'. The developed apron applying the design of opening the body parts without the need for protection from thorns was found to reduce the thermal burden by improving the subjective thermal comfort compared to the existing working clothes in the form of covering the body parts without the need for protecting them from thorns.

5. Satisfaction Evaluation of Protection from Thorns

After repeating the simulation on rose cutting, the satisfaction with the protective function for thorn pricking of the existing working clothes and developed protective clothing was compared according to the body part. The results showed that the developed protective clothing was more satisfactory in all items of the shoulders, chest, arms and hands than the existing working clothes (Table 6). Although the body covering area was reduced for thermal comfort, the apron of the developed protective clothing satisfied the protective function for the parts prone to being pricked by thorns while working.

IV. Conclusions

This study developed and evaluated protective clothing to reduce the exposure to thorn pricking and thermal stress for rose farmers working under hot and humid environments. The requirements of the farmers were identified to determine the shape and design of the protective clothing, and experimental clothing was made through pattern design. The thermal comfort and protective function for thorn pricking of the existing

Table 6. Satisfaction evaluation of protection from thorns (n=10)

Item	Existing protective clothes		Experimental apron		*t*-value
	Mean	S.D.	Mean	S.D.	
Shoulder	3.3	.89	4.6	.52	−3.789**
Chest	3.5	.93	4.6	.52	−3.000*
Arm	2.3	1.28	4.3	1.04	−3.434**
Hands	2.1	.99	4.0	.93	−3.910**

*$p<.05$, **$p<.001$
Strongly disagree (1 point)-Neutral (3 points)-Strongly agree (5 points)

working clothes and developed protective clothing were also compared and evaluated through fit testing, and the following results were obtained.

The design of protective clothing was determined to be the type of apron as the preferred second item in the demand survey. To reduce the burden of the sequence while working in a greenhouse, the closure method was selected using the buckle and end to open the back of the body as much as possible, and the half-sleeve attachable type was used to protect the arm severely pricked by thorns while working. The thermal comfort for existing working clothes and developed protective clothing was evaluated through the fit experiment. As a result, the heart rate and skin temperature did not show any significant differences but the temperature and humidity inside the clothing showed significant differences in the back part.

The physiological responses to temperature and humidity, showing the climate inside the clothing, revealed a difference in the experimental clothing in the back part. The open type design to reduce the covering area as much as possible helped reduce the burden of the objective and subjective thermal burden. The conclusion that comfort can be increased by applying the design elements and changing the opening area and position of the opening of the clothing was the same as that in previous studies (Choi et al., 2005b; Chu, 1998; Kim et al., 1990). The developed protective clothing to which the design of the back part without the need for protection from thorns and opening one sleeve was found to be more effective for reducing the thermal burden than the existing working clothes.

The limitations of this study were as follows. First, it is difficult to generalize the results because the survey area was limited to certain areas and the number of those surveyed was small due to the low accessibility to farmers growing facility horticulture roses. On the other hand, the results were sufficient to identify the features and problems of work because only facility horticulture farmers were selected as the research subjects, and the facility horticulture rose fields were visited several times for the survey. The second limitation was that this study did not conduct further valid experiments except for the natural result that the developed protective clothing was more suitable than the existing clothes in terms of thermal comfort.

Despite these limitations, this study may be significant in terms of the development of protective clothing for thorny plants. Another significant factor is that it selected materials that can prevent thorn pricking among the materials currently on the market and sought to minimize the manufacturing cost through the application of a design that can reduce the thermal burden. These were considered to help to improve the likelihood of uptake in farming areas. Through this study, it is expected that more functional materials will be applied in the future and agricultural work clothes with an ergonomic design effective for work will be developed.

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