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# Improvement of Shade Structures for Ginseng Cultivation

**Seoung Hee Kim[1], Min Young Kim[1], Sang Bong Lee[1], In Bea Jang[2], Kyou Seung Lee[3]***

[1]*Department of Agricultural Engineering, National Academy of Agricultural Science, RDA, Suwon, Korea*
[2]*Department of Herbal Crop Research, National Institute of Horticultural & Herbal Science, RDA, Eumseong, Korea*
[3]*Department of Bio-Mechatronic Engineering, Sungkyunkwan University, Suwon, Korea*

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## Abstract

**Purpose:** Using agricultural machinery was not easy in the conventional shading structure, specified as a standard facility by standard cultivation methods for ginseng. Thus, this study designed the new types of facility allowing machine access by modifying the conventional type. **Methods:** Two types of facility (i.e. wide roof type and long & short roof type) were designed and installed in an experimental site to evaluate its growing environments and applicability of riding-type cultivator. **Results:** From the results of incoming light measurement, all three types (i.e. two new types and a conventional type) of shading structures blocked the incoming light after 9:00 am. The temperature distribution inside the new types was similar with the one in the conventional type, so the growth of ginseng was in good condition in all three types of facility. The riding-type cultivator was operated well with the low speed first gear of 0.13 m/s in the new types. However, a long & short typed roof needs to be raised 18 cm height in order to use the cultivator. **Conclusions:** With the results of this study, the new types of roof can be used in the ginseng farm in that they satisfied the growing environments for ginseng and the needs for agricultural mechanization.

**Keywords:** Altitude, Azimuth, Post, Riding-type cultivator, Shade net

## Introduction

Ginseng cultivation area in Korea has more than doubled between 1995 and 2010 from 9,375 ha to 19,010 ha. However, farmers have used the same shading structures which Korea Ginseng & Tobacco Research Institute developed and disseminated in 1996. Though a shading structure was specified as a standard facility (A-type and B-type) in standard cultivation methods for ginseng (RDA, 2011), it has made difficult to mechanize the work. Due to the posts on each raising bed, walking cultivators are the only option for farmers to use in the ginseng field (Mok et al., 1996). In U.S. and Canada, large-scale horizontal shading structures have been used to grow the American ginseng Panax Quinquefolius L., and large agricultural machinery can be used. Recently, three northeastern provinces in China have used similar shading structures in the U.S. and Canada.

Since the designation of the standard facility in standard cultivation methods for ginseng in 2001, Yoon (2006) developed a simulation program for structural analysis and evaluated the safety of the standard facility. Nam (2003) reported that new facility model which has weather-related disasters resistant structure should be developed after analyzing the two types of steel post used in the shading structures. There has been little research conducted for the improvement of the ginseng cultivation facility. Lee et al. (2005) compared the growing environments and yields of four types of facility (i.e. two large-scale horizontal

***Corresponding author:** Kyou Seung Lee
**Tel:** +82-31-290-7823; **Fax:** +82-31-290-7830
**E-mail:** seung@skku.edu

shading structures used in U.S. and China, medium-scale type, and standard type) to develop a facility in which tractor can be used. They found out that the yield of 3-year-old ginseng was decreased with three facilities except for one case with the standard type. A shading structure needs to be improved to strengthen international competitiveness of Ginseng as well as to utilize agricultural machines for labor-saving.

Therefore, this study designed new types of facility allowing machine access by modifying a conventional facility and analyzed their feasibility.

## Materials and Methods

Two improved shading structures along with a conventional type of shading structure were installed and assessed their performances. Ginseng seedlings were transplanted on the site. In order to investigate the possibility of ginseng cultivation with the improved shading structures, the environmental conditions such as light and temperature were measured and compared with the ones with a conventional type of shading structure. The feasibility of agricultural machinery and the effects of the shading structure on the growth of crops with the improved shading structures ware also examined.

### Improved shading structures, their design and installation

Newly improved facility with two types, the one wide roof and the other with long & short roof, were designed. They were modified by enlarging the size of the conventional type. Securing work space for agricultural machinery and improving work environments by enlarging a facility were the main points. New structures have one ridge with two furrows on both side for entering and exiting of four-wheeled machine as seen in figure 1. The structure with wide roof had post interval of 2.5 m and maximum height of 2.6 m, while the conventional type had post interval of 1.8 m and maximum height of 1.8 m. The one with long & short roof has a dimension of 2.5 m (long side), 1.1 m (short side), and maximum height of 2.1 m.

The orientation of ridges in the new types was set on the same azimuth (115°) as the one in the conventional type. The location and width of a shade net were set by analyzing the changes of azimuth and altitude of the sun from sunrise to sunset at the summer solstice (July 21) as shown in Figure 2 (a). The widths of shade net were 3.7 m on the wide roof type and 2.2 m (long side) and 1.6 m (short side) on the long & short roof type to minimize incoming light on the ridges at 10:00 am as shown in Figure 2 (b) and (c).

Two types of the improved model were installed at Jinbu County, which is an experimental site of the National Institute of Horticultural & Herbal Science located in Gangwon Province. Three units of multi-span shading structures with a wide roof and 3 units with a

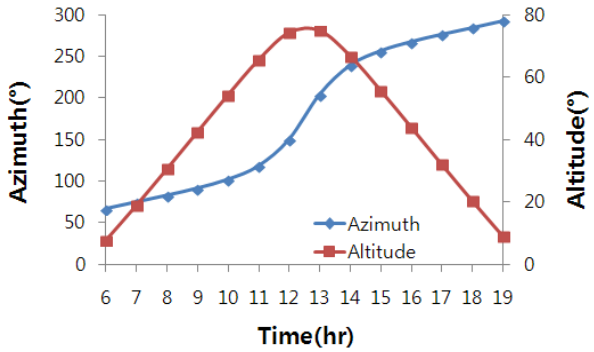
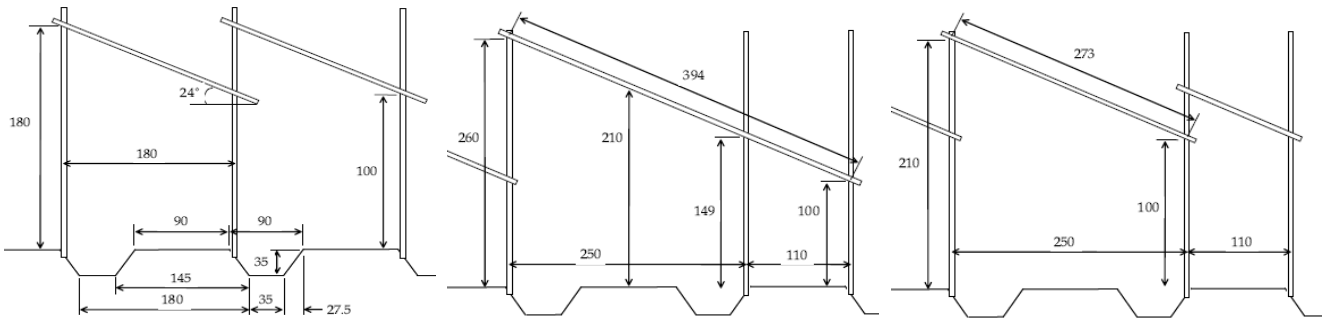
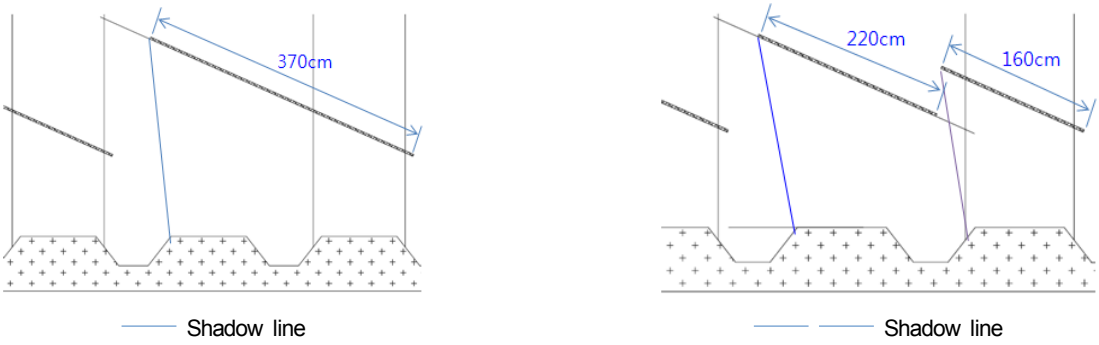



**Figure 2.** Azimuth and altitude of sun (6.21, the summer solstice).




(a) Conventional (b) Wide roof (c) Long & short roof

**Figure 1.** Three types of shading structure.




*at 10:00 am (azimuth 101.8°, elevation 54.4°) of the summer solstice

(a) Wide roof (b) Long & short roof

**Figure 3.** Design of a shade net based on azimuth and altitude of sun.

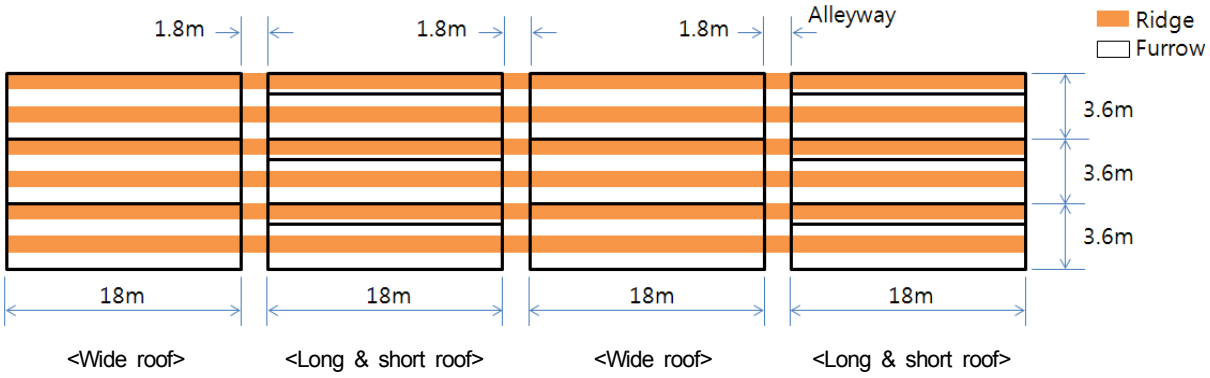
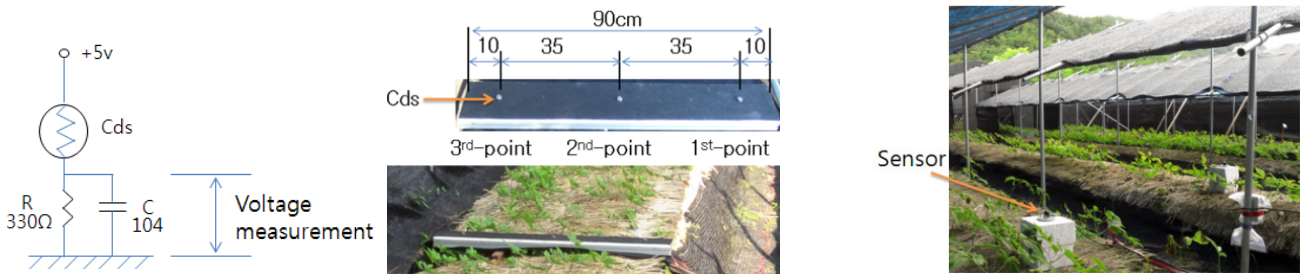



**Figure 4.** Arrangement of shading structures.

long & short roof were installed and arranged one by one for ginseng cultivation experiment as shown in Figure 4.

## Measurement of incoming light and light environment inside shading structures

Optical sensing module for measuring incoming light inside shading structures was composed of three Cds photo sensors on the frame as shown in Figure 5. The size of the sensing module was same as the one of the ridge (i.e. 90 cm), and two Cds photo sensors were fixed on 10 cm inward from both sides of a module and one on the middle of a module. One module with 3 sensors was installed at a conventional type because a shading structure was the same on each ridge. However, two modules with 6 sensors were installed at the new types because the roof covered the two ridges. Since the resistance value of a Cds photo sensor changed depending on the amount of light, the voltage value measured from the one side of a module was converted into a signal at a data collection device and stored at a computer. The experiments continued




(a) Measurement device for incoming light (b) Quantum sensor

**Figure 5.** Measurement device for incoming light and Quantum sensor.

from the sunrise to sunset in order to measure the time when the incoming light reached on the ridges. Photo sensors were named by the number: the one under a high roof side as 1st-point, the one on middle as 2nd-point, and the one under a low roof side as 3rd-point.

A total of six quantum sensors were also installed to measure the photosynthesis photon flux density (PPFD) which was used for analyzing the inside light environments of shading structures. Sensors were placed at near the topmost leaves where crop grew. Each sensors were located as followings: 1) one (#1) at a conventional type, 2) two at a wide roof type, #2 under a high roof side and #3 under a low roof side, 3) two at a long & short roof type, #4 under a long roof side and #5 under a short roof side, and 4) one (#6) outside facility. Recorders (HR-20, apogee instruments, USA) and quantum sensors (UE-130, Useem Instrument Inc., Korea) were used.

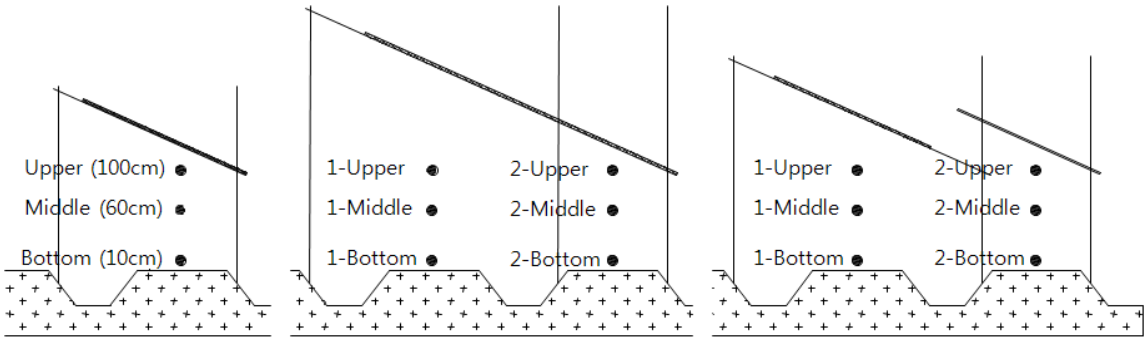
## Comparing temperature changes in each type of shading structures

The temperature differences between inside and outside of a facility were measured in all types of shading structures because the plants can be damaged by high temperature inside a facility. The experiments were conducted from August 3rd to 8th, 2012, and Figure 6 depicts the measuring spots above the ridges in each type. The temperature was measured at three spots: 10 cm, 60 cm, and 100 cm above a bed, respectively. Thermo Recorder (TR-72Ui, T&D, Japan) was used.

## Test of applicability of agricultural machinery inside shading structures

Since the height of the improved types was determined to allow the four-wheeled vehicles to enter and exit, mini tractors and riding-type cultivators were selected suitable for the new types. However, the wheel width of the tractor was not fitted into the width of the alleyway (1,500 mm), and the ground clearance of the tractor was low for the height of the ridge (350 mm) as shown in Table 1. As a result, the rear drive wheels of the riding-type cultivator need to be reversed on the axle to increase the clearance width up to 1,610 mm. In addition, the wheels for sprayer need to be mounted to increase the clearance height up to 770 mm. The cultivator, therefore, can be utilized with these modifications inside shading structures.

A pest control inside shading structures is more labor intensive than any other farm work (Kang et al., 2003). Thus, the applicability of pest control practices with the riding-type cultivator in the improved types was examined.




(a) Conventional (b) Wide roof (c) Long & short roof

**Figure 6.** Location of measuring points.

**Table 1.** Specifications of tractors and a riding-type cultivator

| Category | Tractors | | | Riding type cultivator |
|---|---|---|---|---|
| | D Co. | K Co. | T Co. | |
| Max Output (ps) | 34 | 36 | 35 | 20 |
| Overall Length (mm) | 2,820 | 3,320 | 3,287 | 2,240 |
| Overall Width (mm) | 1,430 | 1,500 | 1,315 | 1,610 (Reversed wheel) |
| Ground Clearance (mm) | 270 | 290 | 310 | 740 (Wheel for sprayer) |

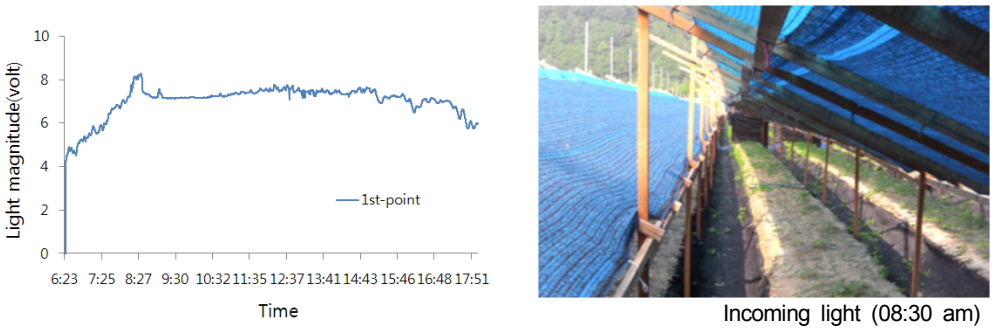
### Effects of the shading structure on the growth of ginseng

A total of 70 ginseng seedlings were transplanted and the hill spacing was 7 rows and 10 columns in November 2011. Each plot size was 90 cm in width by 180 cm in length. All experiments repeated three times, which means a total of 210 ginseng seedlings and 3 plots were used. The plant growth of survival rate, plant length, stem length, leaf length and leaf width, stalk diameter, and chlorophyll content were investigated in July 2013 and used for statistical analysis. The plant length, stem length, leaf length and leaf width were measured using a ruler and caliper. Chlorophyll meter (SPAD-502, Konica minolta, Japan) for measuring chlorophyll content was used.

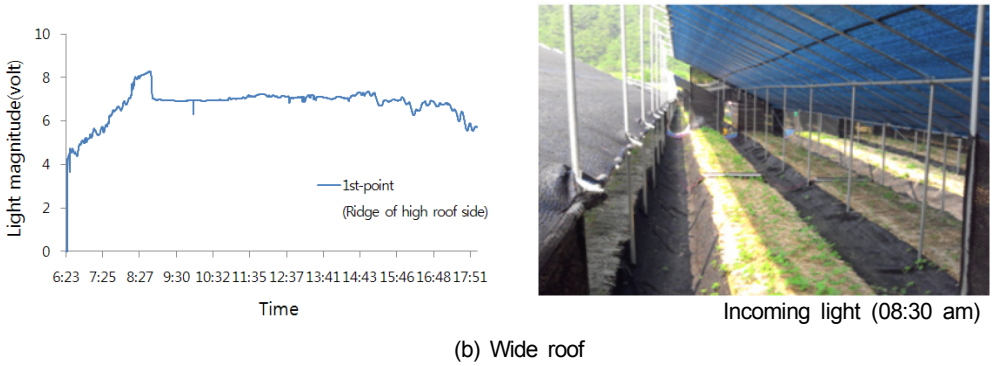
## Results and Discussion

### Analysis of incoming light and light environment inside shading structures

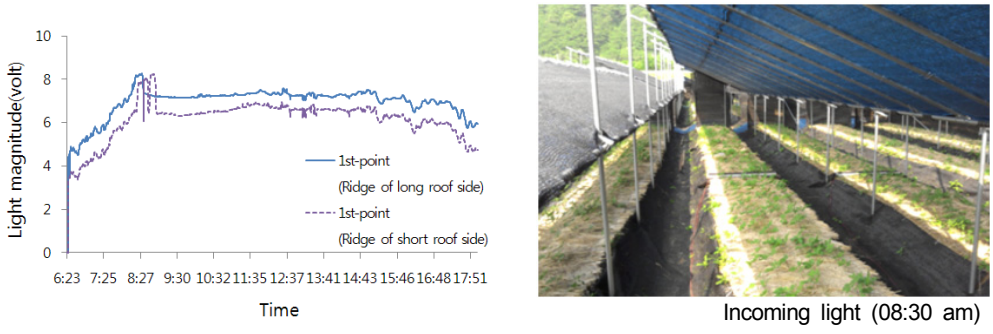
The incoming light was measured on 1st-point of the sensing module in every type except for the low roof side of wide roof type as shown in Figure 7, at the conventional type (8:09~08:48am), the wide roof type (08:13~08:49am), and the long & short roof type (long roof side : 08:08 ~08:39am, short roof side : 08:22~08:54am), respectively. There was no incoming light after 08:54 am in all three types of shading structures. The maximum width of the incoming light was 40 cm at the wide roof type, and 18 cm at both conventional type and long & short roof type. The improved types, both wide roof type and long & short roof type, showed the similar performance with the conventional




(a) Conventional




(b) Wide roof




(c) Long & short roof

**Figure 7.** Measurement of incoming light (June 21st, 2012).

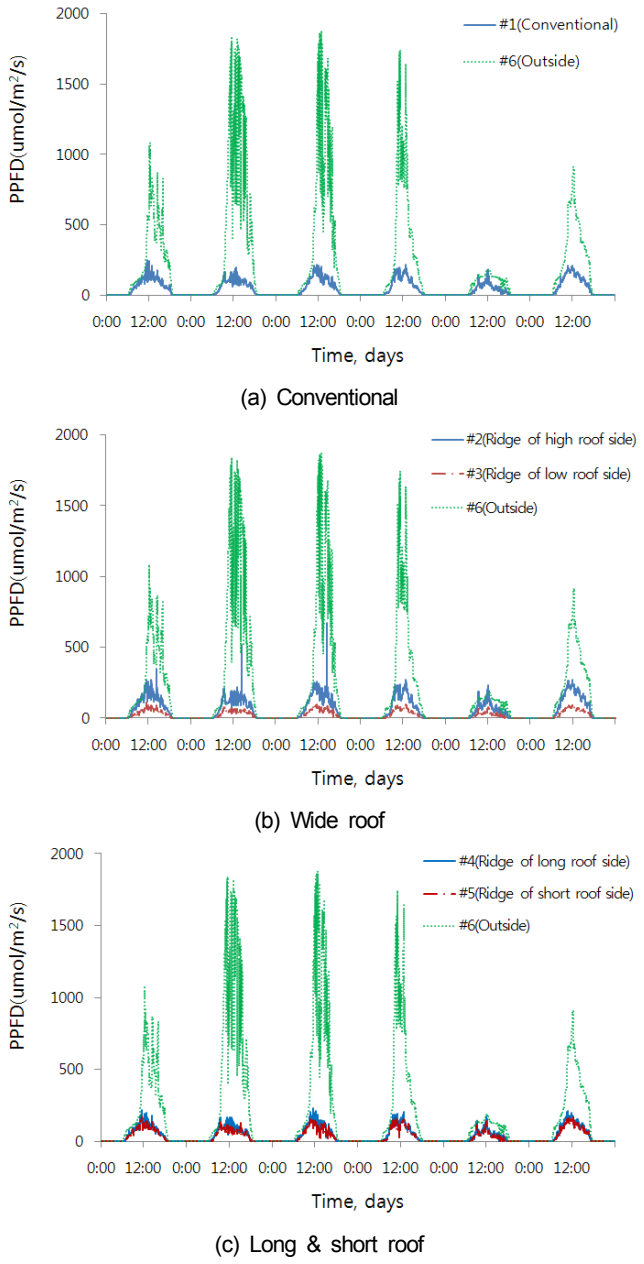



**Figure 8.** Photosynthetic photon flux density measurement (Sep. 7th ~ 12th, 2012).

type in terms of blocking incoming light after 9:00 am. The new types also satisfied the condition that light until 9:00 am helps the photosynthesis of ginseng (Lee et al., 2005).

During the morning between 8:00 am and 9:00 am, photosynthetic photon flux density (PPFD) on the bed under the wide roof type was different depending on the distance from the roof. The PPFD under low roof side was lower than high side by 64% as shown in Fig. 8 (b). On the contrary, the long & short roof type showed no difference in PPFD regarding the distance from the roof. The PPFD in the wide roof type decreased under the low roof side because high side of the rear roof shed a shadow to the low side of the front roof. Thus, materials with low shading rate should be used for the low roof side in order to ensure the PPFD.

## Analysis of temperature changes in each type of shading structures

The results of the temperature measurement showed no significant difference between inside and outside facilities. This was due to the experimental site located in highland area above an elevation of 700 m. As shown in Figure 9, temperature inside the facility was higher than outside temperature during the day time and was lower than the outside temperature during the night.

The dates showing temperature differences were August 3rd, 4th, and 8th. Inside temperature on August 4th in the conventional type was spatially analyzed based on three spots: 7°C higher than outside temperature at upper spot (100 cm above the bed), and 4°C higher at middle (60 cm above the bed) and bottom (10 cm above the bed) spots as shown in Figure 10. Meanwhile, inside temperatures of the wide roof type and long & short roof type were higher than outside by 4~5°C at all three spots. Since the new types were modified by increasing the

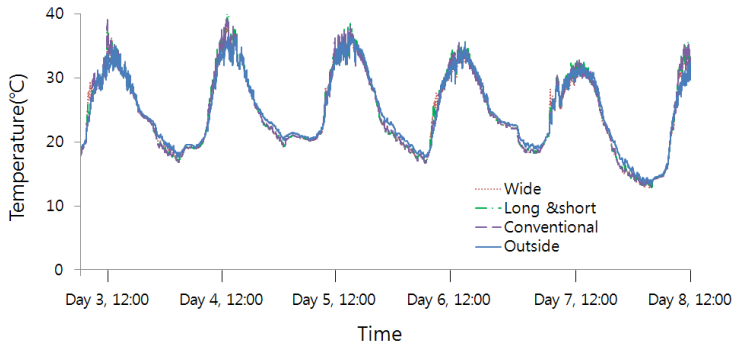



**Figure 9.** Temperature measurement inside and outside facilities (August 3rd ~ 8th, 2012).

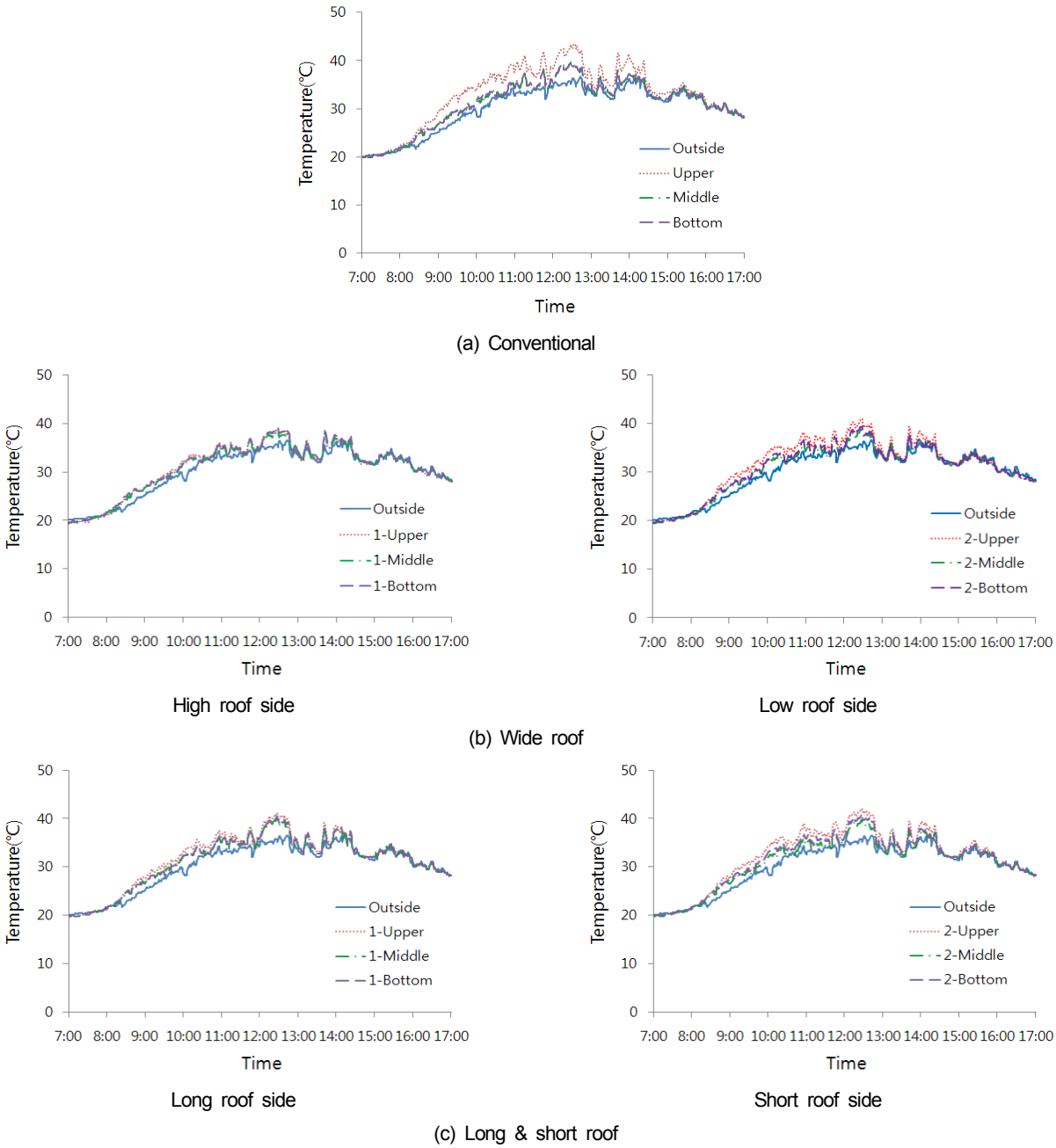



**Figure 10.** Temperature differences between inside and outside facilities (August 4th, 2012).

height of the conventional type, the temperature of the upper spot was lower than the one of conventional type by 2°C. However, the temperature at the middle and bottom spot area, in which the plants grow, showed no difference in all types of facility.

## Test of applicability of agricultural machinery inside shading structures and growth of ginseng

After modifying a horizontal boom sprayer for the cultivator into a vertical type, the pest control practices were conducted inside shading structures. In order to maximize the wheel width of the cultivator, the rear drive wheels were reversed on the axle. The riding-type cultivator was operated well with the low speed first gear of 0.13 m/s as shown in Figure 11, but the low speed second gear damaged the ridge with its wheels. In addition, the cultivator did not work well in the long & short roof type because the height of the types was lower than the operator's sitting height by 18 cm. Meanwhile, the

**Figure 11.** Pest control practice with riding-type cultivator.

operation of cultivator in the wide roof type did not show any problem with height.

Table 2 and Figure 12 show the growth of ginseng in three types of shading structures. In comparison of new types to conventional one, there were no significant differences in the growth characteristics of ginseng (plant length, stem length, leaf length, leaf width, and stalk diameter), standing crop rate, and chlorophyll content.

## Conclusions

This study developed two types of shading structures to utilize the agricultural machinery and compared the incoming light, inside temperature, and growth of the ginseng with the conventional type. The application of the riding-type cultivator was also examined. The results of the study are as follows:

(1) Two types of facility were designed: wide roof type and long & short roof type. The experimental procedure using new types was repeated with the conventional type.
(2) The incoming light after 9:00 am was blocked in all three types of shading structures. The wide roof type showed the difference in Photosynthetic photon flux density (PPFD). High PPFD under high roof side and low PPFD under low roof side were observed. On the contrary, the long & short roof type showed no difference in PPFD.
(3) The inside temperatures of the upper spot in two types were lower than the one of the conventional type by 2°C due to the higher roof of the new

**Table 2.** Growth of ginseng in three types of shading structures

| Types of facility | Standing crop rate (%) | Plant length | Stem length | Leaf length | Leaf width | Stalk diameter (mm) | Chlorophyll content |
|---|---|---|---|---|---|---|---|
| | | (cm) | | | | | |
| Wide roof | 95.5 | 36.4a† | 18.1a | 4.5a | 12.7a | 3.5a | 32.5 |
| Long & short roof | 93.4 | 37.2a | 18.0a | 4.6a | 12.7a | 3.7a | 32.9 |
| Conventional | 94.1 | 35.9a | 17.9a | 4.2a | 11.7a | 3.2b | 34.8 |

†Mean seperation within columns by Duncan's multiple range test (P<0.05)

(a) Conventional (b) Wide roof (c) Long & short roof

**Figure 12.** Ginseng plants in three types of facility.

models. However, temperature at the middle and bottom spot area, in which plants grow, showed no difference in all types of facility.

(4) The riding-type cultivator was operated well with the low speed first gear of 0.13 m/s after modifying the spryer of the cultivator into a vertical boom sprayer.

(5) The growth of ginseng was in good condition in all three types of facility.

(6) With the results of this study, two new types of shading structures can be used with some improvements such as increasing in PPFD of the wide roof type and increasing the height of long & short roof type.

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

## Acknowledgement

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