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A Hybrid-Type Plant Factory Using Sliding Cultivation Shelves

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Abstract. The paper deals with a hybrid-type plant factory system, which uses automatic sliding cultivation shelves and a hybrid lighting system of sunlight and LEDs to promote plant growth. In our plant production system sunlight is reflected to plants by using a solar tracking system during the day. LED lights are then used during the nighttime or on cloudy or rainy days. We also study reduction ratios of sunlight reflected into the plant production system and uniform irradiation capability of LED light. In this study, the automatic sliding cultivation shelves are designed to have three layers. Our plant production system is finally verified by growing ginseng seedlings.

Keywords: Hybrid-type plant factory, heliostat, LED light, sliding cultivation shelves, solar tracking system

1 Introduction

In 1957 a vegetable production system was introduced in Denmark applying a concept of mass plant production. In Japan, some researchers had paid attention to plant factories in the early 1970s and a closed-type plant factory had been developed in 1990s. It was verified in previous research [1] that LED light was effective for plant growth. In Korea, plant factories drew researchers' attention in the 1990s. Applications of IT and LED technologies to plant factories have then been studied since the mid-2009. The selection of light source, environment control, and online monitoring systems has been researched popularly since the 2000s [2].

In this research we propose a hybrid-type plant production system, which uses both sunlight and artificial light. We also apply sliding cultivation shelves with three layers to use sunlight illumination more efficiently. In this study we briefly discuss solar tracking control, automatic sliding cultivation shelves, and a controller for measuring and recording the growth of plants.

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2 Solar tracking and LED lighting systems

2.1. Performance tests for a solar tracking system

Fig. 1 shows tracking performance test results for four heliostats. These performance tests are conducted to confirm how well the heliostat tracks azimuth and elevation angles of the sun. In Fig. 1, a blue line (target) indicates actual movement of the sun and a red line shows actual movement of the heliostat. Our test results verify each heliostat tracks the sun's movement with sufficiently small errors as expected.

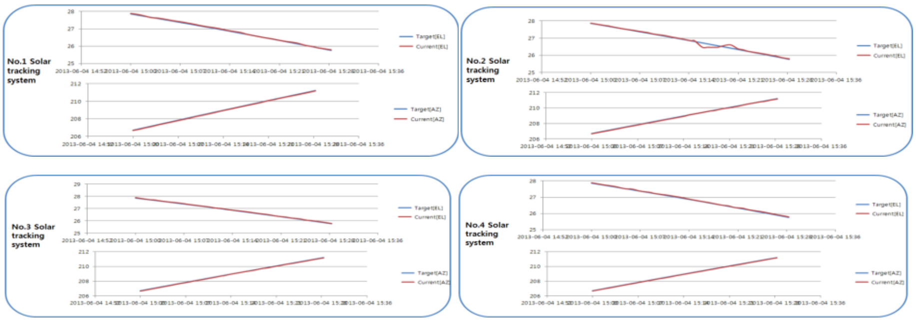

Fig. 1. Performance test results of the solar tracking system.

2.2. Tests of light reduction rate for sunlight and uniform irradiation of LED light

Table 1 provides illumination values measured from experiments. Illumination intensity was measured three times on each location of cultivation shelves (upper, middle, and lower). As a result, an average light reduction rate on the shelves is 4.29% per meter, which is satisfactory for plant cultivation.

Table 1. Reduction rate of solar light.

	Location		Reduction rate(%/m)
	Upper cultivation shelf	Lower cultivation shelf	
Measured values (Lux)	551	527	4.36
	552	530	3.98
	550	525	4.54
Average reduction rate of solar light			4.29

While turning the LED light on, we measured illuminance of the LED light on 16 prescribed points. Resulting measurements are provided in Table 2. In this case, the standard error of measurements is 7.07%, which indicates we can obtain relatively good uniform irradiation of LED lights.

Table 2 Illumination measurement of the LED light.

Illumination (Lux)				Standard error
658	785	730	717	7.07%
729	749	755	706	
703	725	753	730	
718	736	714	705	

3 Cultivation shelves, monitoring system and growth record of plants

Automatic sliding shelves are used to maximize illumination of incoming sunlight via heliostats in the plant production system. Fig. 2 shows a 3D modeling of cultivation shelves. As shown in Fig. 2, the cultivation shelves are comprised of three layers such that upper and lower shelves can be slid relative to the middle shelf. Sliding cultivation shelf is automatically controlled by using a pneumatic cylinder.

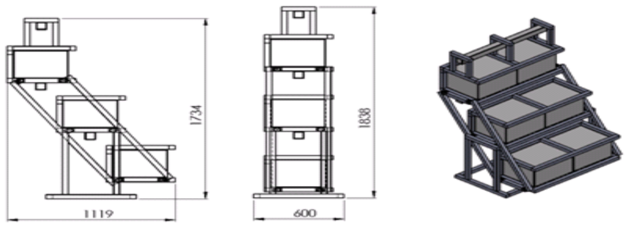

Fig. 2 3D modeling of cultivation shelves

A plant monitoring and control system is used to monitor and record plant growth. This system can also be used to analyze the situation when a problem occurs and respond to it even if an administrator is absent. Our monitoring system can store measured data such as temperature and water content to observe persistent plant growth. Six cameras are also used to monitor plants in real time whose pictures are captured from videos every two hours. Fig. 3 shows monitoring software for plant production.

Fig. 3. Monitoring software for plant production.

Table 3. Changes in the root length of ginseng seedlings applying several different ratios of LED lighting (Unit (cm)).

Date / Ratio of LED lighting	May 27	June 5	June 11	June 18
1:1	8.0±2.5	11.0±2.2	11.4±1.9	12.8±0.5
1:2	9.9±1.9	9.9±2.7	12.7±2.3	13.0±0.7
1:3	11.2±1.6	12.2±0.3	12.4±0.7	13.1±0.3
1:4	11.6±3.5	12.4±0.9	13.2±0.8	14.4±1.3

Table 3 provides changes in the root length of ginseng seedlings by using several different ratios of red to blue LED light while solar intensity is uniform. When the blue and red LED ratio was 1:4, roots of ginseng seedlings had grown slightly faster compared to other mixing ratios.

4 Conclusions

In this study we propose a plant factory system equipped with plant cultivation shelves and a hybrid illumination system. Since both sunlight and artificial light are applied in this factory, plant production becomes more efficient compared to traditional methods. Our experimental results show that sunlight can be uniformly illuminated in the plant production system by using the proposed automatic plant cultivation shelves with multi-layers. In particular, we find roots of ginseng seedlings had grown slightly longer compared to other parts when the blue and red LED ratio was 1:4.

References

1. Y. Hashimoto, ‘Recent Strategies of Optimal Growth Regulation by the Speaking Plant Concept’, Acta Horticulture, Vol. 260, pp.115-121 (1989)

2. Y. Paek, J. G. Jeon and H. K. Kim, ‘Performance Analysis of Photovoltaic Power Generator in a Closed-type Plant Production System’, Proceedings of the Korean Society for Agricultural Machinery Autumn Conference, October 31, Jeju, Korea, Vol. 18, No. 2, pp.301-302 (2013).

