EFFECTS OF LIGHT CONDITION ON THE GROWTH OF LAI CHAU GINSENG SEEDLINGS (*Panax vietnamensis* var. *fuscidiscus*) IN A PLANT FACTORY

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1. INTRODUCTION

Panax ginseng is one of the most important medicinal plants in Asian countries such as Vietnam, South Korea, India and China. The ginseng root is normally harvested after four or six years of growth, which has been commonly used for manufacturing health supplements [1]. However, literature has reported that the ginsenosides content in ginseng leaf is higher than in the root for the same cultivation duration. The highest ginsenosides content has been reported for 1 year old ginseng leaves. Ginseng seedlings could be harvested after approximately 4 to 6 weeks [2, 3].

Growth and quality components of vegetables are affected by many environmental factors such as temperature, humidity, light, soil water content and nutrition. Light plays a key role in plant life, determining their photo-morphogenesis and photosynthesis rate [4]. The integration, quality, photoperiod and intensity of red, far-red, blue, UV-A (320-500 nm) and UV-B (280-320 nm) light have a profound influence on plants by triggering physiological reactions to control their growth and development [5, 6]. Light emitting diodes (LEDs) are solid-state, long-lasting and durable sources of narrow-band light that can be used in a variety of horticultural and photo-biological applications [5], including controlled research environments [4] lighting for tissue culture [6] and supplemental and photoperiod lighting for greenhouses [7]. The effects of photosynthetic photon flux density (PPFD) and red to blue light ratios on the leaf shape and concentration of functional compounds in basil were studied in a paper by Hikosaka [8]. They suggested that basil growth, appearance, and functional and aromatic compound concentrations can be adjusted as needed by manipulating the PPFD and R/B ratio, although R/B 4.0 at PPFD of 300 caused malformed leaves. Cultivation using dwarf cultivars and the effect on tomato fruit quality under UV-A irradiation conditions in a plant factory were investigated in a study by Kobayashi [9]. They found that UV irradiation had a positive effect on fruit size per fruit and carotenoid content. UV irradiation did not affect the yield per plant. When cultivating tomato plants in a plant factory, fruit size and composition improvements are expected by appropriately adjusting the time and intensity of UV irradiation for each cultivar.

With the revised Ginseng Industrial Act, ginseng seedlings have become a new medicinal vegetable with high consumer demand. However, the existing research data on ginseng production does not reflect the changed reality; there are insufficient studies on ginseng seedlings, as the general study focus has been on hydroponics ginseng cultivated by the previous method that applied nutrient solutions to nursery soil or water for 3 to 4 months [10]. In the case of 4-months-old hydroponic ginseng,

the total amount of ginsenosides in stems and roots is 1.1 - 1.5%, while the leaves have 13.3 - 16.1%, which is 12 times greater than the amount in stems and roots [11, 12]. However, during the different stages of cultivation, the proportion of ginsenosides in ginseng changes [13, 14].

Therefore, the objective of this study was to investigate the effects of light conditions including light type, intensity and photoperiod on the growth of *P. vietnamensis* var. *fuscidiscus* in a plant factory.

2. MATERIALS AND METHODS

2.1. Plant materials and growth conditions

Three experiments were designed and performed in a plant factory. *Panax vietnamensis* var. *fuscidiscus* seedlings (Figure 1) were cultivated under different light conditions including light type, light intensity, and light photoperiod. One-year-old ginseng seedlings were transplanted into cultivation beds. In experiment 1, three different light types were examined, including WBU, white LED, and yellow LED (590 nm). LEDs were distributed in one bar with light color ratio of 5 : 2 : 1 for W : B : U. Three levels of light intensity (2000, 4000 and 6000 lux) were set up in experiment 2 while three photoperiods (2/22, 4/20, and 8/16 day/night circle hours) were evaluated on the formation of the main root in experiment 3. Detailed environmental information for each experiment was summarized in Table 1. We used a wireless sensor network system to monitor and control the environmental conditions automatically in the plant factory such as temperature, humidity, carbon dioxide concentration (CO_2), light photoperiod. Due to the purpose of our project, the plants were harvested after 4 weeks of transplanting. Totally, 292 plants (92 plants for each experiment 1 and experiment 2, and 108 plants from experiment 3) were collected to measure the physical parameters of plant growth. Effects of light conditions on plant growth were described through the analysis of plant parameters including number of leaves, plant length, stem diameter, root diameter and plant weight. Plant parameters were measured immediately after cutting from the plants.

Table 1. Growth conditions

Item	Experiment 1	Experiment 2	Experiment 3
Light sources	Yellow LED; WBU; White LED	WBU	WBU
Photoperiod (hours)	8/16	2/22; 4/20, 8/16	8/16
Intensity (lux)	4000	4000	2000, 4000, 6000
Temperature (^oC)	20 ± 1		
CO_2 (ppm)	1000 ± 100		
Substrate	Pe : V : P* = 50% : 15% : 35%		
* *Pe: peatmoss* *V: vermiculite* *P: perlite*			

2.2. Statistical analysis

Analysis of variance (ANOVA) is a simple technique test of whether there are differences between groups or treatments. However, one-way ANOVA is the simple form and we still cannot identify which means differ significantly. Then, Duncan's multiple range test at the 5% level was a procedure performance of the post-hoc comparison test. In this study, we applied Duncan's multiple range test to identify significant difference between pairs of individual factors using the SAS program (SAS Institute, Cary, NC) [15].

Figure 1. Seedlings of *Panax vietnamesis* var. *fuscidiscus*

3. RESULTS AND DISCUSSION

Figure 2 showed the growth characteristics of ginseng seedlings plotted against three light types (WBU, yellow LED, and white LED). Generally, plant growth was greater under WBU LED than that under white and yellow LEDs. However, the standard deviation of plant growth was also increased from 1.7g to 2.3g for plant weight, and from 5.2 mm to 14.8 mm in plant length. Plant weight was high under WBU LED (0.76g) whereas the standard deviation was also higher than that under other LEDs (± 1.9g). The results of Duncan's range test at the 5% level indicated that plant growth of ginseng was significantly different for plant length. Plant length of ginseng seedlings grown under WBU LED was the highest length.

Growth characteristics of ginseng seedlings in three different light intensities after 4 weeks of transplanting the spouts are shown in Figure 3. Although the results of Ducan's range test at the 5% level indicated that plant growth characteristics were not a significant difference, plant growth in the light intensity of 4000 lux was higher than that in the light intensity of 2000 and 6000 lux. Additionally, the number of lateral roots of ginseng seelings grown in the intensity of 4000 lux was greater than that in the other light intensity levels.

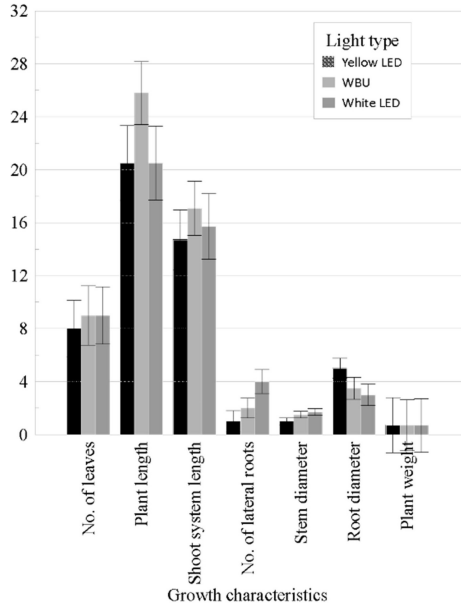

Figure 2. Effects of light types on ginseng growth

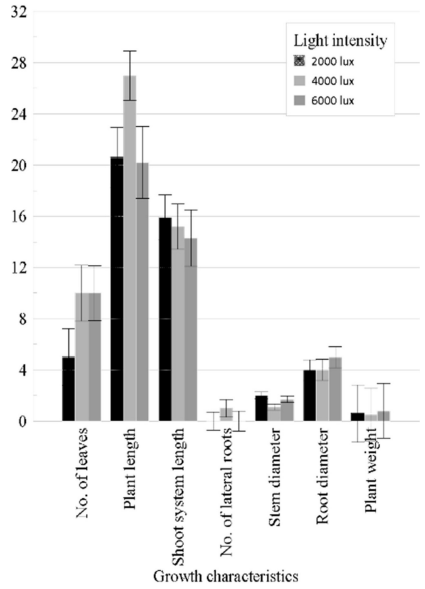

Figure 3. Effects of light intensity on ginseng growth

Figure 4 shows the effects of three light photoperiod levels on ginseng growth. We found that growth characteristics increased with increasing day time, especially for number of leaves, plant length, and shoot system length. In contrast, standard deviation values of growth characteristics of ginseng in photoperiod of 8/16 hours were slightly higher than that in the other light photoperiod levels. However, stem diameter and root diameter in three light photoperiod levels were not significantly different.

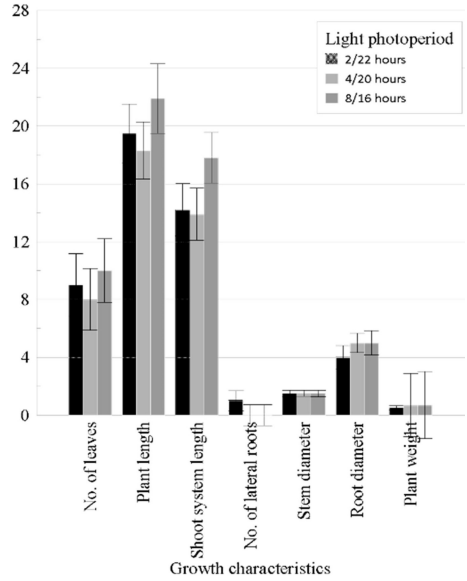

Figure 4. Effects of light photoperiod on ginseng growth

4. CONCLUSION

This study investigated the effects of light conditions on the growth of *Panax vietnamesis* var. *fuscidiscus* grown in a plant factory, where three different types of light and three light intensity levels, and three photoperiod levels were examined. According to the results, the optimum light for growth was WBU LED. In additional, the growth characteristics of ginseng were higher in the intensity of 6000 lux and the photoperiod of 8/16 day/night circle hours. Effects of light condition on functional components of *P. vietnamensis* var. *fuscidiscus* should be investigated in future work.

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SUMMARY

Panax vietnamensis var. *fuscidiscus*, called "Lai Chau ginseng" in Vietnam, is a new variety of *P. vietnamensis*, which was first found in Lai Chau province, the northwest region of Vietnam. The objective of this study was to investigate the effects of light condition (light source, intensity and photoperiod) on the growth of *P. vietnamensis* var. *fuscidiscus* in a plant factory (actively controlled factors such as temperature, light, humidity, nutrition, etc.). One-year-old seedlings were transplanted to a controlled-environmental in a plant factory. The effects of three different light sources White : Blue : UV (WBU), white LED, yellow LED, three levels of intensity (2000, 4000, 6000 lux) and three levels of photoperiod (2/22, 4/20, and 8/16 hours) were evaluated on the growth of ginseng seedlings. The sample was collected after 30 days of transplanting. Results showed that the main root of *P. vietnamensis* var. *fuscidiscus* was formatted under WBU light source with intensity of 6000 lux and photoperiod of 8/16 hours. Effects of light condition on functional components of *P. vietnamensis* var. *fuscidiscus* should be investigated in future work.

Keywords: *Light condition, light intensity, light photoperiod, Lai Chau ginseng, ánh sáng, cường độ sáng, thời gian chiếu sáng, sâm Lai Châu.*

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