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Effects of Light Quality on The Growth of Tissue Cultured Transplants

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Abstract

Tissue cultured transplants cultivated under two LEDs with different light quality and conventional fluorescent lamp as artificial light sources, were examined and compared the growth of plantlets. Culture conditions were 23±1°C, 16 hours illumination / 8 hours dark, PPFD at illumination was 100 μmol m^{-2} s^{-1} for all light sources. The light sources used for this examination were a cool white fluorescent lamp (FL) and two types of straight-tube type LEDs, Tecoled G2 (cool white: G2) and Tecoled G4 (warm white: G4). In strawberry, 'Akihime', there was no significant difference in total fresh weight (FW) and leaf number per plantlet under the three different light sources. However, for 'Tochiotome' and 'Toyonoka', the total FW and leaf number were larger under G4. Compared with FL, the petiole length tends to be shorter in both of LEDs. In sweet potato, total FW per plantlet was greater under G4 in 'Narutokintoki' and 'Beniharuka' and under G2 in 'Beniazuma'. The differences in response to the different light sources were relatively great depending on the cultivars in sweet potato. In Japanese horseradish, the value of all measured parameters was the maximum under G2, and the overall growth was also the most vigorous under G2.

INTRODUCTION

As an artificial light source for the tissue culture transplant production, most production facilities have used fluorescent lamps. However, due to the entry into force of the "Minamata Convention on Mercury" in Japan, legal measures were set for fluorescent lamps which are mercury-based products, for storage and disposal. Furthermore, from the basic energy plan of the Japanese government, conversion from fluorescent lamps to SSL (Solid State Lighting) such as light emitting diodes (LEDs) has been promoted, and the announcement of discontinuation of fluorescent lamp manufacturing is successive from manufacturers in Japan. In recent years, the use of LEDs has spread in various scenes of plant cultivation (Mitchell *et al*., 2015).

Many research reports have investigated the influence of monochromatic light on the growth and morphogenesis of in vitro cultured plants using LEDs (*e.g*. Shimizu *et al*., 2013; Alvarenga *et al*., 2015; Ramĭrez-Mosqueda *et al*., 2017; Silva *et al*., 2017). From the viewpoint of production workability, white light is desired as artificial light. However, most of the white LEDs are made to emit white light by covering the blue LED chip with some phosphors, and the light quality of the irradiation light is changed by the fluorescent substance (phosphor) to be used (Viršile *et al*., 2017). It has not been clarified how much such difference in light quality affects the quality of cultured transplants.

Then, tissue cultured transplants inoculated by Verde Co., Ltd. (Toyohashi city, Aichi prefecture) which is one of the representative tissue culture transplant production companies in Japan, cultivated under two LEDs with different light quality and conventional fluorescent lamp as artificial light sources, were examined and compared the growth of plantlets.

MATERIALS AND METHODS

For the experimental materials, we used 3 cultivars of strawberry (*Fragaria ×ananassa* (Duchesne ex Weston) Duchesne ex Rozier, 'Akihime', 'Toyonoka' and 'Tochiotome'), 3 cultivars of sweet potato (*Ipomoea batatas* (L.) Lam., 'Narutokintoki', 'Beniazuma' and 'Beniharuka') and 1 cultivar of Japanese horseradish (*Eutrema japonicum* (Miq.) Koidz. Syn. *Wasabia japonica* (Miq.) Matsum., 'Mazuma').

All of inoculated explants (9 explants per plant box) moved to the irradiation facility installed in the culture room of the Tokyo University of Agriculture (TUA) Atsugi campus (Atsugi city, Kanagawa prefecture) as soon as possible after transplanting to the plant box (made of polycarbonate, top side 7.5 cm, height 9.5 cm) containing the modified Murashige and Skoog (1962) media at Verde Co., Ltd., and started the light quality treatment. Culture conditions were 23±1°C, 16 hours illumination / 8 hours dark, PPFD at illumination was 100 μmol m^{-2} s^{-1} for all light sources.

The light sources used for this examination were a cool white fluorescent lamp (FL40SS-N / 37, Toshiba Lighting & Technology Co., Ltd. (Yokosuka city, Kanagawa prefecture); hereinafter referred as FL) which is usually used in Verde Co., Ltd., and two types of straight-tube type LEDs of Toshin Electric Co., Ltd. (Shibaura, Minato ward, Tokyo), Tecoled G2 (cool white; hereinafter G2) and Tecoled G4 (warm white; hereinafter G4). The respective emission spectra of three light sources measured by a spectrometer (USB2000 Fiber Optic Spectrometer, Ocean Optics Inc., Dunedin, Florida, USA) are shown in Figure 1.

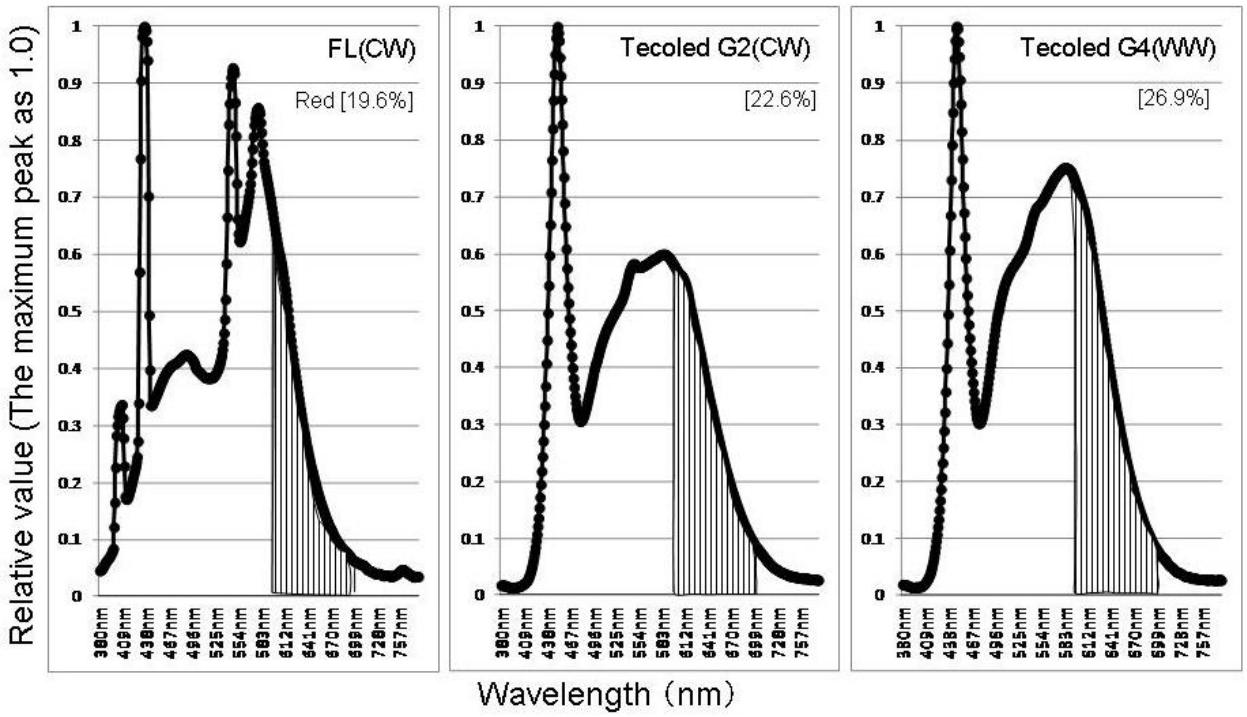

Figure 1. Respective emission spectra of three light sources. The value (%) shown in parentheses is the ratio of the red-light component (600-700 nm) to the total emitted light. CW: cool white, WW: warm white

After 3 to 4-week culture under each of light sources, the fresh weights of top and roots and the number of leaves per each plantlet were measured. Leaf lamina length and petiole length of the longest leaf, and the longest root length were further measured according to the plant species.

In the case of strawberry cultured transplants, when the petiole length is longer, the transplants shield the light from each other, which is undesirable. Compared with FL, the petiole length tends to be shorter in both of LEDs (Table 1), resulting in a compact appearance as a whole under LEDs.

RESULTS AND DISCUSSION

Strawberry

In a cultivar ‘Akihime’, there was no significant difference in total fresh weight and leaf number per plantlet under the three different light sources. However, for ‘Tochiotome’ and ‘Toyonoka’, the total fresh weight and leaf number were larger under G4 (Table 1).

Sweet potato

Total fresh weight per plantlet was greater under G4 in ‘Narutokintoki’ and ‘Beniharuka’ and under G2 in ‘Beniazuma’. There was no significant difference in leaf number in ‘Narutokintoki’. However, the leaf number of ‘Beniharuka’ and ‘Beniazuma’ tended to be larger in G4 (Table 1). In sweet potatoes, the differences in response to the different light sources were relatively great depending on the cultivars.

Table 1. Effects of light source on the growth of in vitro cultured transplants in strawberry and sweet potato.

Plant	Cultivar	Light source	Total FW (g/plantlet)	Leaf number per plantlet	Petiole length (cm)	Longest root length (cm)
Strawberry	Akihime	FL	0.43	4.9	3.9a	5.8a
		G2	0.45	4.4	2.7b	3.9b
		G4	0.44	4.8	2.4c	4.0b
	Tochiotome	FL	0.92a	5.8a	2.2	6.4a
		G2	0.73b	4.3b	1.7	5.1b
		G4	0.96a	5.4ab	1.9	5.7ab
	Toyonoka	FL	0.54b	5.6ab	2.3a	5.8b
		G2	0.47c	5.3b	1.7b	6.5a
		G4	0.88a	6.4a	1.9b	5.5b
Sweet potato	Narutokintoki	FL	0.81c	4.2	3.1b	12.3
		G2	0.96b	4.2	3.6a	13.0
		G4	1.15a	4.2	3.1b	13.0
	Beniazuma	FL	0.55b	4.1a	4.8a	15.8
		G2	0.71a	3.6b	3.7b	13.9
		G4	0.56b	4.2a	3.6b	15.3
	Beniharuka	FL	0.64b	6.9b	3.7b	20.1b
		G2	0.80a	7.1b	4.6a	24.3a
		G4	0.84a	7.8a	4.3a	19.2b

n = 10-30. Different letters within cultivar indicate a significant difference at the 5% level by Tukey's test.

Japanese horseradish

The value of all measured parameters was the maximum under G2, and the overall growth was also the most vigorous under G2 (Table 2).

From the above results, for strawberry, sweet potato and horseradish, it is considered that there is no serious problem to the production of tissue culture transplants even if it is replaced with the LED light source used this experiment from FL.

Table 2. Effects of light source on the growth of in vitro cultured transplants in Japanese horseradish.

Plant	Cultivar	Light source	Total top FW (g/plantlet)	Total root FW (g／plantlet)	Length of the largest leaf (cm)	
					Leaf lamina	Petiole
Japanese horseradish	Mazuma	FL	0.21b	30.0b	1.5b	2.4b
		G2	0.40a	60.0a	1.9a	2.9a
		G4	0.36a	41.7b	1.8a	2.8a

n = 10. Different letters within cultivar indicate a significant difference at the 5% level by Tukey's test.

However, when estimating the results in detail, it was found that strawberry and sweet potato with high growth under the G4 light which the red-light component is relatively large, and horseradish with vigorous growth under the G2 light which is relatively large in the blue light component. Thus, favorable light quality is different among plant species. In the near future, when switching the light source from fluorescent lamps to LEDs, it is necessary to select the light source by paying attention to this point.

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