

Development of LED Lids for Tissue Culture Lighting

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Abstract

A novel system equipped with LED as light source for tissue culture (TC) plantlets production was developed. The system consists of a control system, shelf with multi-layers, and a new type of TC vessels equipped with double lids with LEDs at the inner surface of the outside lid. Twenty types of LED lids were available and by changing the lid, the light quality can be altered. The system has 8 layers and 40 TC vessels per layer, leading to 320 vessels per bench. A mini-version of the system was also developed equipped with 2 layers and 12 containers in each layer. In all systems, day/night light cycle and light quantity (10 levels) can be adjusted. This paper presents fundamental measurements of various types of lids, features of the system and provides examples of how to use these lids to conduct photo-phyto related research.

INTRODUCTION

Tubular florescent lamps (TFL) are the most popular artificial light source in tissue culture (TC) for plantlet production. A review on artificial lighting of TC and transplants production was conducted by Fang and Jao (2000). Movable light mounting fixture was developed and installed in a plant factory for the production of TC plantlets and young potted *Phalaenopsis* using TFL (Fang and Jao, 1996; Lai, et al., 2001).

TFLs have wide spectrum and are categorized by color temperature such as cool white (5000~6000 K), day light (4000~5000 K) and warm white (<4000 K), etc. TFL provides lots of green light, which green leaves reflect, leading to low efficiency per quantum of light within PAR range. At present, LED is the most promising alternative to TFL due to its long usable lifetime and its capability of mixing different chips, thus creating any desired quality of light.

Tubular LED lamps (TLL), LED panels, and LED light bar are commercially available and can be used to replace the TFL installed on top of a growth bench. However, uniformity on bench is quite poor. Fang and Jao (1996) developed software to simulate uniformity of the bed based on given arrangement of TFLs. Proper spacing of lamps, side lighting at both ends of the lamp and reflectors should be used to provide better uniformity.

Determination of LED spectrums for plant related applications are mainly based on knowledge of the absorption spectrums of Chlorophyll a (peaks at 430 and 662 nm), Chlorophyll b (peaks at 453, 642 nm), phytochrome R (peak at 660 nm) and phytochrome FR (peak at 730 nm). In general, LEDs with peak wavelength of 450, 660 and 730 nm were selected for blue, red and far red light.

LED has promising future in horticultural lighting (Jao and Fang, 2001). CCFL and HEFL get more attention than before, compare with LEDs, due to its high intensity, high efficiency and similar cost with TFL. CCFL and HEFL were used in TV / Notebook backlighting, but were replaced by LED just recently. Horticultural lighting could be their way out to have a new market.

All light sources mentioned above such as: TFL, TLL, CCFL, HEFL, LED panel, LED light bar, were mounted on top of the growth bench facing down if used for TC production. After installed, the spectrums were fixed. Light source need to be replaced to change the light quality which takes a lot of work. Design of LED lids aims at solving this as well as solving uniformity problems under the bench.

MATERIALS AND METHODS

A TC vessel with two lids was developed. The vessel and its inner lid (Fig. 1 top photo), made of Poly-Carbonate (PC), can be autoclaved, withstand up to 121 degree C and 1.2 atmospheric pressure. The bottom of outer lid equipped with 6 LED lamps as shown in the bottom photo of Fig. 1. Inside each lamp, there are 6 chips, leading to 36 chips in total per lid. Only 6 essential types of light quality were considered for the prototype. Later, increased to 8 and recently, totally 20 types of LED lids were developed.

Table 1 shows spectral distribution of 'essential 8', they are: cool white (color temperature, CT: 5000 K), warm white (CT: 2700 K), 8R1B, 7R1G1B, 3R3B3IR, 6R, 6B, and 6IR. Those with IR were the newly add to 'essential 6'.

Note that the term 8R1B does not imply the ratio of quantum (in micro-mole.m⁻².s⁻¹) is 8 to 1. In stead, it represents ratio of number of LED chips used for the particular lid. In total, there are 36 chips per lid. 8R1B means 32 red and 4 blue chips per lid and 7R1G1B means 28 red, 4 green and 4 blue chips per lid. Peaks of wavelength for B/G/R/IR led chips used in this study were 450±3, 525±3, 660±5, 730±5 nm, respectively.

A cart, entitled 'Giant E-Light', with 8 separate layers was developed as shown in the left of Fig. 3. Light intensity of each layer can be controlled separately and day/night hours can be controlled by build-in timer. Each layer has 40 vessels, thus 320 vessels per cart. The right side of Fig. 3 shows a smaller system, entitled 'mini E-Light'. This system has 2 layers with timer for each layer and has 12 vessels per layer.

RESULTS AND DISCUSSION

Left photo of Fig. 2 shows the 'Giant E-Light', which has 8 layers with 1 timer and holds 40 vessels per layer. Features of the Giant E-Light system are as follows:

1. Unique design of TC vessel with 2 lids. Upper lid contains 6 LED lamps, each with 6 chips.
2. High efficiency in terms of electricity consumption due to the distance from light source to plants is greatly reduced compare with the traditional bench system.
3. High uniformity can be achieved inside the vessel through proper design of LED lamps inside the lid and the white side dividers installed. The dividers

block all light from 4 sides thus no pollution from light next to each other can be ensured.

4. High Space utilization can be reached. In a traditional TC bench, the density is 138 vessels/m². But for Giant E-Light, the density is 482 vessels/m². That is a 3.5 times increase per same amount of floor area.
5. Light quality can be easily changed by changing the lid of the vessel. Totally, 20 types of lids available. Spectrums can be found in Fig. 3.
6. The light intensity can be adjusted up to 10 levels. Each layer can have different intensity. Different lids have same intensity (PAR) at same level as shown in Fig. 4.
7. Day/Night controlled through Timer: Giant E-Light has only 1 timer and Mini E-Light has 2 timers, thus the light cycle at both layers can be different.
8. Easy to use: Each vessel has power cable and can be easily plug in within the cell.
9. Great tool for Experiment: Giant E-Light allows researchers to conduct experiments with 5 replicates with at most 64 treatments. Mini E-Light allows researchers to conduct 3 or 4 replicates with at most 8 or 6 treatments, respectively.
10. Highly efficient system for mass production. A TC lab can be redesign using cargo container. One 40 feet container can have 38 Giant E-light, capable of growing 12160 vessels/cargo, that is 462 vessels/m².

Fig. 2 (right photo) shows the 'Mini E-Light', which has 2 layers with independent timer controlling light cycle. Each layer holds 12 vessels.

Table 1 shows spectral distribution of 8 previously developed LED lids under blue, green, red and far red categories. Wave band of each category is listed in the first row of Table 1. Ratios of quantum of each category for each type of lid were listed in Table 1.

'Giant E-Light' and 'Mini E-Light' equipped with timer(s) for light cycle control. Also, 10 levels of light intensities can be adjusted easily. Using such equipment, conducting research related to light intensity and light cycle are quite straightforward. Table 2 shows ratio of LED chips used per lid in 20 types of LED lid. Tables below used the lid number listed in this Table demonstrating possible research that required alteration of light quality.

Table 3 shows group of lids (No. 1, 4, 8, 12, 14, 16, 17) can be used to study the effects of red-blue mix light. Table 4 shows group of lids (No. 3, 5, 6, 9, 13, 15 and 7, 10) for the study of the effects of red-blue ratio with concurrent infrared (1IR or 2IR as the base). Table 5 shows group of lids (No. 4, 6, 7, 11, 17) can be used to study the effects of red, blue or IR with concurrent blue light (3B as the base). Table 6 shows group of lids (No. 16 to 20) can be used to study the effects of mono-wavelength vs. white LED light. Group of lid no. 1,2 and 3 can be used to study the effects on supplemental red, infrared or green light incorporated with concurrent red and blue mix light (7R1B as the base). Group of lid no. 8 to 11 and 16 can be used for the studies on the effects of supplemental red, blue or infrared light incorporated with concurrent red light (3R as the base). Group of lids no. 4 and 5, 12 and 13, and 14 and 15 can be used to study the effects of supplemental blue or infrared under 6R2B, 2R6B and 1R7B mix light, respectively.

CONCLUSIONS

A novel system equipped with LED as light source for tissue culture (TC) plantlets production was developed. Twenty types of LED lids are available and by

changing the lid, the light quality can be altered. Replacing vessels is as simple as plug in and out. The ‘Giant’ and ‘Mini’ systems provide great flexibility in conducting light quality, intensity and light cycle related research at the same time. They are great tools for conducting photo-phyto related TC research.

Literature Cited

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Tables

Table 1. Spectral distributions (quantum ratio) of ‘essential 8’ LED lids

Types of LED Lids	Blue 400~500nm	Green 500~600nm	Red 600~700nm	Far Red 700~800nm
CW (5000 K)	26 %	46	26	2
WW (2700 K)	10	45	41	4
8R1B	13		87	
7R1G1B	13	7	80	
3R3B3IR	46		42	12
6R			100	
6B	100			
6IR				100

Table 2. Ratio of LED chips per lid in 20 types of LED lid.

nm	660	450	730	525		660	450	730		660	450	730		660	450	730
Lid	R	B	IR	G	Lid	R	B	IR	Lid	R	B	IR	Lid	R	B	IR
01	8	1			06	5	3	1	11	3	3	3	16	9		
02	7	1		1	07	4	3	2	12	2	7		17		9	
03	7	1	1		08	3	6		13	2	6	1	18			9
04	6	3			09	3	5	1	14	1	8		19	CW (5500 K)		
05	6	2	1		10	3	4	2	15	1	7	1	20	WW (2700 K)		

Table 3. Group of lids for the study on the effects of red-blue mix light

Lid No.	R	B
16	9	
01	8	1
04	6	3
08	3	6
12	2	7
14	1	8
17		9

Table 4. Group of lids for the study on the effects of red-blue ratio with concurrent infrared (1IR or 2IR as the base)

Lid No.	R	B	IR
03	7	1	1
05	6	2	1
06	5	3	1
09	3	5	1
13	2	6	1
15	1	7	1
07	4	3	2
10	3	4	2

Table 5. Group of lids to study the effects of red, blue or IR with concurrent blue light (3B as the base)

Lid No.	R	B	IR
17		3+6	
04	6	3	
06	5	3	1
07	4	3	2
11	3	3	3

Table 6. Group of lids to study the effects of mono-wavelength vs. white LED light

Lid No.	R	B	IR
16	9		
17		9	
18			9
19	CW (5500 K)		
20	WW (2700 K)		

Figures



Fig. 1. Tissue culture vessel with 2 lids (top), outer lid flip over shows 6 lamps per lid (bottom)



Fig. 2. Tissue culture cart developed (Left: Giant E-Light, 8 layers, 40 vessels per layer, L107-W62-H195 in cm, power consumption: 110VAC/12A or 220VAC/5.5A; Right: Mini E-Light, 2 layers, 12 vessels per layer, L66-W40-H80 in cm, power consumption: 110 VAC/0.61A or 220VAC/0.3A).

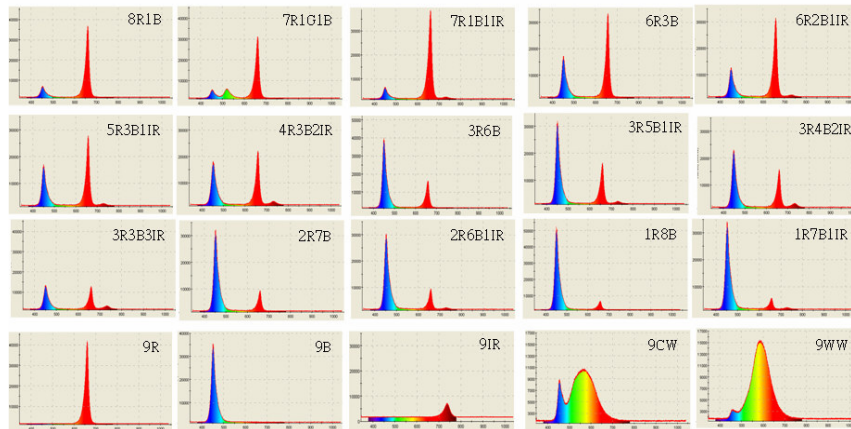


Fig. 3. Spectrums of 20 types of LED lid developed

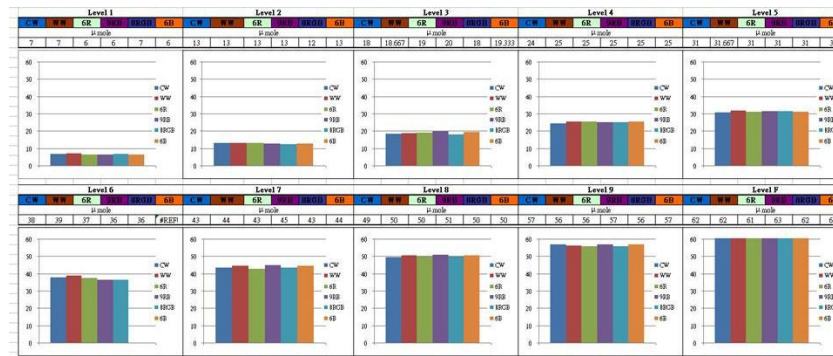


Fig. 4. Comparison of 10 stages of light intensities of 6 lids including: CW, WW, 6R, 9R1B, 4R1G1B, and 6B.