Effect of Artificial Light Supplement in Transcontinental Sea Cargo on the Flowering of Young Spiking *Phalaenopsis*

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Abstract

***Phalaenopsis* is the most important horticultural product for export in Taiwan. Since 2004, US admitted the import of potted *Phalaenopsis* with moss media from Taiwan. The transcontinental shipping had changed from bare-rooted plant by air into potted plant by sea, due to the cost by sea was much cheaper and the damage of potted plant was much less. If the product for export was the potted orchid with flower stalk, it would reduce the cultivation period in greenhouse in US. This meant increasing the greenhouse turnover ratio and reducing the management cost. However, the dark stress for orchids was the major restriction in the sea transport. No illumination during transport for 3-4 weeks inhibited photosynthesis, and suppressed the stalk growth and flower induction. The key technology for exporting spiking orchids was to provide the suitable light environment for maintaining the succeeding growth of the flower stalk during the shipping. The objective of this research was to investigate the effect of artificial light supplement in the transcontinental sea cargo for young spiking *Phalaenopsis*. Two kinds of energy-saving light source, high power light-emitting diode and T5 fluorescent tube, were applied in this research. This paper presents the comparison of the effect on the spiking orchid by using these two light sources and different illumination strategy during the transport period.**

INTRODUCTION

Phalaenopsis is the most important horticultural product for export in Taiwan. For the sake of the epidemic prevention, the US government allowed only bare-rooted orchids imported to US. To remove the moss and replant the orchid in pots were labor-consuming works. Lin and Lin (2005) found that the bare-rooted treatment and the dark environment during the transport were the major stresses to the orchid. The bare roots were vulnerable by removing the moss. The bare-rooted treatment caused the roots dehydrated and lost the activity. In order to shorten the period of dark stress, the bare-rooted orchids were transported by air. However, the dark transport for only 3-5 days would increase the respiration rate and ethylene production quickly. This would cause serious damage to the orchid roots and lower leaves. Besides the expensive shipping cost, the bare-rooted transport prolonged the recovery period for orchid and the loss percentage was still up to 20-40 % (Chen, 2007).

Since 2004, US admitted the import of potted *Phalaenopsis* with moss media from Taiwan. The transcontinental shipping had changed from bare-rooted plant by air into potted plant by sea, due to the cheaper shipping cost and less damage loss. In 2006 and 2007, the orchid export to US increased dramatically. In 2008, the export amount to US exceeded the amount to Japan. Nowadays, the US market plays a very important role to Taiwan, just like the Japan market.

The dark stress in the sea transport was still the major restriction for potted orchids. No illumination during transport for 3-4 weeks inhibited photosynthesis, and suppressed the plant activity. When arriving ashore, these shipped orchids should take two or more weeks for recovery before the successive flower-forcing task by cool temperature treatment. Lin and Lee (1998) found the light intensity in early stage of cool temperature treatment would affect the time to spiking and the spiking number, and the light intensity in latter stage would affect the number of flower. Wang (1995) reported the period to anthesis would spend 123 days since the end of dark storage if providing enough light intensity. Insufficient light intensity would postpone the anthesis up to 216 days. The longer the orchids stayed in the greenhouse, the lower overturn ratio of greenhouse it would take. Lower greenhouse overturn ratio meant the more investment for hardware and management. This would increase the production cost dramatically.

The management cost for flower forcing in Taiwan is one third of the cost in US. If the product for export was the potted orchid with flower stalk, it would reduce the cultivation period in greenhouse in US. This meant increasing the greenhouse turnover ratio and reducing the management cost. The key technology for exporting spiking orchids was to provide the suitable light environment for maintaining the activity of the flower stalk during the shipping. However, to provide the sufficient illumination and to maintain the cool environment in the shipping cargo is very difficult because of the power restriction by the cargo itself. High power light emitting diode and T5 fluorescent tube were the most well-known products of energy saving. They both were possessed of the following advantages: high illumination with low energy consumption, compact size and low heat discharge, etc. These novel energy-saving light sources maybe provide good solutions to overcome the problem.

The objective of this research was to investigate the effect of artificial light supplement in the transcontinental sea cargo for young spiking *Phalaenopsis*. Two kinds of energy-saving light source, high power light-emitting diode and T5 fluorescent tube, were applied in this research. This paper also presents the comparison of the effect on the spiking orchid by using these two light sources and different illumination strategy during the transport period.

MATERIALS AND METHODS

Table 1 showed three different kinds of light spectrum provided by two different energy-saving light sources, light-emitting diode (LED) tube and T5 fluorescent tube. The spectrum included cool white 5500K by LED (CW, 20W), red/blue light combination (660nm/450nm = 80:20) by LED (RB, 13W), cool white 6500K by T5 fluorescent tube (FL, 28W). The light tubes were installed on the pot plant trolleys. The shelf dimension of the pot plant trolley was 127 × 55 cm. Three treatments of these different spectrums, including three CW LED tube(CW×3), four R/B LED tube (RB×4) and three FL tube (FL×3), provided the light environment of around PAR 50 μmol/m2/s measured under 25 cm to the light tube. In order to reduce the power consumption in the cargo, two treatments by removing a LED CW tube (CW×2) and by reducing the light duration (CW×3-8) were added to determine the effect of less light integral on the plant during storage. Two controlled treatments were conducted in this study: the Dark treatment with orchids stored under dark environment to simulate the current method of dark transportation and Greenhouse treatment with orchids grown in the flower-forcing greenhouse without storage in the whole experiment.

Orchids of two commercial cultivars, white flower *Phal.* Sogo Yukidian 'V3' and red flower *Dtps*. Jiuh Bao Red Rose 'OX1194', were used in the experiment. The mature orchids with 6 leaves, leaves span 30-35 cm were grown in 10.5-cm-diameter pots filled with moss as the growing substrate and moved into the flower-forcing greenhouse since 22 Jun. 2009. The cool temperature in this greenhouse was set at day/night 25/18 ºC and the illumination was 15,000 lux. After 2 months of cool temperature pre-treatment for flower-forcing, 140 plants of each cultivar with spiking were selected for the experiment. The average stalk length of the white flower and the red flower cultivars were around 20 cm and 30 cm respectively.

The experiment was divided into two stages: storage stage and successive growth stage. In storage stage, the orchid trolleys with different light source were placed in a temperature controlled chamber to simulate the sea cargo transport. The temperature was set at 18±1 ℃ and the humidity was not controlled. The storage period stared at 25 Aug. 2009 and ended at 26 Sep. 2009 for 4 weeks. When the storage period ended, the plants were irrigated throughout and then send to the flower-forcing greenhouse again to simulate the successive growth for orchids in the US greenhouse.

RESULTS AND DISCUSSION

The stalk length was measured before the 4-week storage. When the storage ended, the plants were moved to the flower-forcing greenhouse again for successive growth. The stalk length was also measured at the beginning and 4 weeks later since the successive growth stage. In Table 2 showed the stalk length increment in Dark treatment was only 9 cm for white orchid and 5 cm for red orchid at the end of 4-week storage. The other treatments with light supplement are much better than the Dark treatment. This meant, as expected, dark stress affected the stalk elongation seriously. Higher light integral (CW×3, RB×4, FL×3) seem better than lower light integral (CW×3–8, CW×2). Although the light integral in ‘CW×2’ and ‘CW×3–8’ treatments were the same, the increment in treatment ‘CW×2’ seemed better. This implied that the treatment of longer light duration with lower light intensity was better to overcome the dark stress.

The stalk increment in all of the storage treatment would accelerate in the successive growth stage since plants were moved to the greenhouse again. In the column ‘Week 4’ of Table 2, the increments in treatment ‘CW×3’ and ‘CW×2’ were better than other storage treatment with light supplement. The spectrum of cool white provided by LED was probably suitable for maintaining the orchid activity during storage. Compared to storage treatments, the control treatment ‘Greenhouse’ had the longest increment at the beginning but slowed down at the successive growth stage. In column ‘Blossom percentage’ of Table 3 and Table 4, the blossom percentages of white and red orchid in treatment ‘Greenhouse’ were 44% and 87.5%, respectively. That meant the stalks were almost well developed and this was the reason why the increment slowed down.

The amount of bud and flower on each stalk, the amount of fully open flower on each stalk and the diameter of fully open flower were recorded at the end of 4^{th} weeks and the 7th weeks in the successive grown stage. The effects of light supplement during storage on the flower quality of orchids of white and red flower were shown in Table 3 and Table 4, respectively. At the end of the 4th week in the greenhouse, the average amount of buds and flowers per plant in Dark treatment was less than the amount in other treatment with light supplement. In average, 2 to 3 buds per plant increased 3 weeks later. At the 7th week, the treatment 'CW×3' had the most number of buds in red orchid, just the same as the control treatment 'Greenhouse'. However, the trend did not appear in the white orchid. The amounts of fully open flower in the 'Dark' treatment at the 7th week, 0.5 and 1.4 flowers per plant for white and red orchid respectively, was also less than the other treatment significantly. The dark tress in the storage postponed the flower development seriously. The light supplement with cool white spectrum, no matter supplied by LED or fluorescent tube, would improve the postponement.

Table 5 summarized the orchids with 1, 3 or 5 fully open flowers at the end of the 7th week. If the market size was set at orchid with 3 fully open flower, for red orchid, the treatments of 'CW×3', 'RB×4', 'FL×3' provided almost equal probability of 87.5%, 90.0%, and 86.7% to collect the orchids with at least 3 flowers. However, the 'RB ×4' treatment also provided probability of 30% orchids with at least 5 flowers but 'CW×3', and 'FL×3' only 12.5% and 6.7% respectively. This implied the cool white spectrum achieved more synchrony on the flower development. The orchid production in synchrony would reduce the difficulty in management and improve the turnover ratio of greenhouse.

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Tables

Table 1. The light intensity and power consumption of different treatments of light supplement in experimental storage stage.

Light source	Light: Intensity PAR, μmol/m²/s	Light: Duration D/N, hr	Light integral mol/m²/d	Daily Power Consumption kW-hr / d
CW×3	54.3±12.1	12/12	2.35	0.72
RB×4	47.9±10.8	12/12	2.07	0.62
FL×3	54.4±13.9	12/12	2.35	1.01
CW×3–8	54.3±12.1	8/16	1.56	0.48
CW×2	40.0±11.9	12/12	1.73	0.48
Dark	0	0/24	0	0
Greenhouse	≈ 270 (15,000 lux)	13/11	> 10	0

Table 2. Length and length increment of Phalaenopsis flower stalks before, after storage and 4 weeks since the end of the storage

Treatment	Light integral mol/m²/d	White orchid *Phal.* Sogo Yukidian 'V3'			Red orchid *Dtps.* Jiuh Bao Red Rose 'OX1194'		
		Initial Length, cm	Length Increment, cm		Initial Length, cm	Length Increment, cm	
			Storage	Week 4		Storage	Week 4
CW×3	2.35	18.9 a	12.7 b	23.0 bc	30.9 b	8.9 b	13.0 a
RB×4	2.07	17.7 a	11.7 c	25.9 ab	33.5 a	8.6 bc	9.2 c
FL×3	2.35	20.4 a	13.2 b	24.2 bc	31.9 b	8.3 bcd	9.2 c
CW×2	1.73	18.4 a	11.1 c	27.8 a	31.1 b	7.9 cd	11.7 ab
CW×3–8	1.56	17.9 a	9.9 d	24.6 bc	31.8 b	7.5 d	9.3 c
Dark	0	18.3 a	9.0 d	22.3 c	31.7 b	5.0 e	10.0 bc
Greenhouse	> 10	18.9 a	28.1 a	15.9 d	31.8 b	18.3 a	5.4 d

Means followed by the different letters in each column are significantly different at 5% level by Duncan's Multiple Range Test.

Table 3. Effect of Different light supplement during storage on the flower quality of white orchid *Phal.* Sogo Yukidian 'V3'

Treatment	Light integral mol/m²/d	Buds no./plant		Flowers no./plant		Blossom percentage%		Flower Diam. cm
		Week 4	Week 7	Week 4	Week 7	Week 4	Week 7	

CW×3	2.35	4.0 b	5.7 d	0.1 b	1.6 bc	7.7	61.5	11.6 a
RB×4	2.07	3.8 b	5.7 d	0.0 b	1.0 cde	0.0	55.6	11.8 a
FL×3	2.35	4.0 b	5.9 bcd	0.0 b	2.1 b	0.0	81.3	11.8 a
CW×2	1.73	3.9 b	6.8 a	0.0 b	1.4 cd	0.0	71.4	10.8 a
CW×3–8	1.56	3.6 b	5.7 cd	0.0 b	0.8 de	0.0	44.4	11.7 a
Dark	0	2.7 c	6.5 ab	0.0 b	0.5 e	0.0	37.5	10.9 a
Greenhouse	> 10	5.5 a	6.4 abc	1.0 a	3.6 a	44.0	92.0	12.0 a

Means followed by the different letters in each column are significantly different at 5% level by Duncan's Multiple Range Test.

Table 4. Effect of Different light supplement during storage on the flower quality of red orchid *Dtps.* Jiuh Bao Red Rose 'OX1194'

Treatment	Light integral mol/m²/d	Buds no./plant		Flowers no./plant		Blossom percentage%		Flower Diam. cm
		Week 4	Week 7	Week 4	Week 7	Week 4	Week 7	
CW×3	2.35	5.1 b	7.1 a	0.7 cd	3.5 b	43.8	100.0	9.3 a
RB×4	2.07	4.7 c	6.3 c	1.3 b	3.8 b	80.0	100.0	9.3 a
FL×3	2.35	4.5 cd	6.3 c	0.8 cd	3.5 b	60.0	100.0	9.2 a
CW×2	1.73	4.4 cd	6.5 bc	0.9 bc	1.5 c	45.5	81.8	8.9 a
CW×3-8	1.56	4.2 d	6.8 ab	0.5 de	2.9 c	27.3	100.0	9.6 a
Dark	0	3.1 e	6.2 c	0.2 e	1.4 d	23.1	81.8	9.6 a
Greenhouse	> 10	6.0 a	6.8 a	2.6 a	5.6 a	87.5	100.0	9.7 a

Means followed by the different letters in each column are significantly different at 5% level by Duncan's Multiple Range Test.

Table 5. The blossom percentage of orchids with 1,3,5 flowers after 7 weeks since end of storage period

Treatment	Light integral mol/m²/d	White orchid *Phal.* Sogo Yukidian 'V3'			Red orchid *Dtps.* Jiuh Bao Red Rose 'OX1194'		
		1st flower	3rd flower	5th flower	1st flower	3rd flower	5th flower
CW×3	2.35	61.5	46.2	0.0	100.0	87.5	12.5
RB×4	2.07	55.6	11.1	0.0	100.0	90.0	30.0
FL×3	2.35	81.3	43.8	0.0	100.0	86.7	6.7
CW×2	1.73	71.4	7.1	0.0	81.8	54.5	9.1
CW×3-8	1.56	44.4	5.6	0.0	100.0	72.7	0.0
Dark	0	37.5	6.3	0.0	81.8	9.1	0.0
Greenhouse	> 10	92.0	72.0	40.0	100.0	100.0	87.5