Effects of Photoperiodic Cycles and Light Qualities on Shoot Development and Flowering in Petunia Plants

Hiro Shimai

Takamori Orchid Museum 2365 Yamabuki, Takamori – machi, Nagano 399 – 3101

Summary

Petunia × *hybrida* Vilm. plants were exposed to different photoperiodic cycles and light qualities to investigate their shoot development and flowering responses. Plants were reciprocally transferred from long-day (LD), extended by day-extension light by using either far-red rich tungsten light (TL) or red rich cool fluorescent light to short-day or *vice versa*. To produce commercially a high quality petunia having a compact shape and a number of flowers under insufficient light conditions, the initial 15 LD cycles (8-hr daylight followed by 8-hr TL) was most effective. The 30 LD cycles extended by TL resulted in excessive shoot elongation with poor quality. The results indicate that it is possible to improve the shape of petunia plants by using an optimum photoperiodic cycle and light quality.

Key Words: flowering, light quality, *Petunia* × *hybrida*, photoperiodic cycle, shoot development.

Introduction

Petunia × *hybrida* Vilm., possessing a great diversity of flower colours and sizes, is one of the best-selling plants in many countries (Armitage, 1994; Sink, 1984). Although petunia is economically very important, only a few scientific works have been done for commercial production. A particular attention in earlier horticultural works has been mostly given to manipulation of flowering. Petunia plants are normally seed propagated during winter with a short photoperiod and low irradiance, and sold from early spring (Armitage, 1994). To minimize the time from seeding to anthesis, daylight is commonly extended. LD treatment often decreases the time to anthesis, but it results in excessive shoot elongation with fewer lateral branches, thus, lowering plant quality (Piringer and Cathey, 1960; Adams et al., 1999). Tjia (1981) proposed that a good quality petunia was compact and bushy although no clear definition was provided. The number of lateral branches is a factor for bushy shape, while length of main stem and lateral branches are the most important factor affecting plant height. Each lateral branch usually bears only a few flowers simultaneously, so increasing lateral branch can increase the number of flower per plant (Tjia, 1981). Piringer and Cathey (1960) found that the number of internodes formed on main stems between SD and LD treatments was the same, but LD promoted excessive internode elongation. This phenomenon was more clearly seen when TL is applied for day-extension, instead

of FL (Cooke, 1969; Vince-Prue, 1977). How petunia plants respond to a limited number of LD or SD cycles had not been examined. In this work, therefore, overall vegetative growth and flowering responses in petunia plants were examined under different photoperiodic cycles and light qualities.

Materials and Methods

This experiment was performed at the Sutton Bonington Campus, University of Nottingham (United Kingdom). *Petunia* × *hybrida* 'Garden Party White' was propagated from seeds sown onto a seed-tray containing fine peat compost. After germination, the seedlings were individually transplanted to plastic pots (9 cm diam.) when the third true leaf was visible, and maintained in a greenhouse with a mean temperature at $20 \pm 3^\circ\text{C}$. The transplants were regularly irrigated with 1% w/v liquid fertilizer solution. On 30 April, when the fifth true leaf became visible, they were exposed to 10 different photoperiodic cycles in which the LD was extended by either far-red rich TL (100 W tungsten bulbs: $0.7 \text{ W} \cdot \text{m}^{-2}$ at plant height) or red rich FL (40 W cool fluorescent tubes: $1.1 \text{ W} \cdot \text{m}^{-2}$). Therefore, a total of 20 treatments were allocated in this experiment.

- 0 SD (50 LD) = LD throughout
- 5 SD (45 LD) = initially treated by 5 SD then transferred to LD
- 10 SD (40 LD) = initially treated by 10 SD then transferred to LD
- 15 SD (35 LD) = initially treated by 15 SD then transferred to LD

30 SD (20 LD) = initially treated by 30 SD then transferred to LD
 0 LD (50 SD) = SD throughout
 5 LD (45 SD) = initially treated by 5 LD then transferred to SD
 10 LD (40 SD) = initially treated by 10 LD then transferred to SD
 15 LD (35 SD) = initially treated by 15 LD then transferred to SD
 30 LD (20 SD) = initially treated by 30 LD then transferred to SD

All plants in SD received an 8-hr photoperiod (9:00 to 17:00 of natural daylight) and then covered with an automatic opaque curtain system. The LD photoperiod consisted of 8-hr daylight followed by 8-hr additional lighting from either TL or FL, then 8 hr darkness. The wavelength of each light measured by a spectroradiometer is shown in Fig. 1. Ten plants per treatment were reciprocally transferred from SD to LD, or LD to SD after either 5, 10, 15, or 30 days, except 0 SD and 0 LD cycles which were not transferred. The lengths of main stem and of the longest lateral branch in each plant were measured every 5 days. Time to macroscopic

a. Tungsten light (TL)

b. Fluorescent light (FL)

Fig. 1. Light spectrum from tungsten light and fluorescent light.

The light spectrum was measured by a spectroradiometer.

Photosynthetically active radiation range is ca. 400–700 nm.

Table 1. Effects of photoperiodic cycles and light qualities on shoot development and flowering responses in petunia plants.

Treatment	Main stem length ^z (cm)		Lateral branch length ^y (cm)		Lateral branch number ^x		Days to MFBV		Days to Anthesis	
[SD to LD]	Light quality									
	TL	FL	TL	FL	TL	FL	TL	FL	TL	FL
0SD (50LD)	36.0	15.8	33.0	25.1	4.9	6.4	25.6	30.1	34.2	38.8
5SD (45LD)	35.3	15.7	36.3	25.5	4.8	6.8	26.2	29.9	34.5	37.8
10SD (40LD)	34.5	15.5	36.8	25.1	4.8	6.7	26.3	30.3	35.1	38.4
15SD (35LD)	25.8	13.6	31.9	23.7	5.7	7.0	26.1	29.9	35.1	38.3
30SD (20LD)	12.5	9.4	25.8	20.0	6.9	8.4	30.9	28.4	39.2	38.0
[LD to SD]										
0LD (50SD)	7.3	7.3	18.0	18.0	7.8	7.8	29.7	29.7	38.5	38.5
5LD (45SD)	8.5	6.7	17.8	16.7	8.6	8.4	28.9	28.5	38.4	37.8
10LD (40SD)	9.3	7.7	18.1	17.0	7.7	7.0	29.8	29.7	38.9	38.1
15LD (35SD)	16.3	8.6	19.7	17.0	6.3	6.5	26.5	28.9	35.4	37.7
30LD (20SD)	29.0	13.7	28.6	22.5	5.7	6.8	29.6	30.5	34.8	38.2
Significance										
Photo. cycles (P)	***		***		***		***		***	
Light quality (L)	***		***		***		*		***	
P × L	***		***		***		***		***	

Each value shows a mean of 10 plants.

^z Main stem length measured at 45 days after the start of treatments.

^y Longest lateral branch length measured at 45 days.

^x Number of lateral branches counted at 50 days.

*** and * show significance at $P < 0.001$ and $P < 0.05$, respectively.

Fig. 2. Main stem elongation under different combinations of the photoperiodic cycles and light qualities.

flower bud visibility (MFBV) and time to anthesis were recorded when these occurred. All plants were harvested at 50 days after the start of treatments, and the number of lateral branches was counted. Data were subjected to analysis of variance (ANOVA) using Genstat 3.2.

Results

Both photoperiodic cycles and light quality made a significant difference ($P < 0.001$) on main stem length (Table 1). In general, stem elongated more on the plants that received more LD cycles. Plants that received TL had longer main stems than those that received FL. The difference on main stem length within TL treatments became apparent 20 days after the start of treatments, while that within FL treatments was less clear (Fig. 2). A highly significant interaction ($P < 0.001$) of photoperiodic cycles and light quality occurred, in that plants exposed to more LD cycles had longer main stem under both light qualities, but this tendency was significant in the TL treatments. Although shift from SD to LD treatments generally resulted in greater stem elongation, those between 0 SD and 10 SD, or 15 SD cycles showed visibly small differences in terms of plant height.

Lateral branches responded similarly, in that from SD to LD treatments generally accelerated lateral branch elongation compared with from LD to SD treatments in both TL and FL (Fig. 3). The interaction of photoperiodic cycles and light quality on lateral branch length was highly significant ($P < 0.001$). The results showed that lateral branch length between 0 LD and 15 LD cycles within each light quality was similar, indicating

that plant height was visibly unaffected by up to 15 LD cycles. In general, lateral branches tended to be longer than main stem, except in a few treatments.

Plants that received more LD cycles extended by TL formed fewer lateral branches compared with FL treatments, but TL did not completely prevent branch formation. In the 0 SD to 10 SD cycles under TL treatments, approximately 5 lateral branches were formed, while 6 or more branches were formed in other treatments. The results indicate that SD to LD treatments had relatively weak influence on lateral branch formation, but the interaction between photoperiodic cycles and light quality was highly significant ($P < 0.001$) with respect to the number of lateral branches formed.

Both photoperiodic cycles and light quality had a significant effect on time to MFBV ($P < 0.05$ and $P < 0.001$, respectively). Plants that received more LD cycles resulted earlier MFBV, especially under TL. The earliest MFBV was 25.6 days in 0 SD, and the latest was 30.9 days in 30 SD cycles; the difference is highly significant ($P < 0.001$) indicating that time to MFBV was hastened with more LD cycles under TL.

Time to anthesis was highly significantly ($P < 0.001$) affected by photoperiodic cycles, light quality, or their interaction. Regardless of shoot development, TL decreased the interval to anthesis more than did FL. Time to anthesis tended to decrease as the number of LD cycles increased in SD to LD treatments under TL, but it was less obvious under FL. For example, within the SD to LD treatments, the difference between the treatments was 5 days under TL, but only 1 day under FL. In LD to

Fig. 3. Lateral branch elongation under different combinations of the photoperiodic cycles and light qualities.

SD treatments under TL, anthesis occurred after 35.4 days in 15 LD cycles, whereas it happened after 38.9 days in 10 LD cycles.

Discussion

The main stems on plants that received more LD cycles elongated more with fewer lateral branches than did those receiving fewer cycles, especially under TL. Thus the main objective of the current study is to ascertain the optimal number of photoperiodic cycles for shoot development, the production of better quality petunia plants, and minimizing the production period was accomplished. The data show that 15 LD cycles extended by TL seems to be the most efficient for both lateral branch formation and anthesis. Although Kaczperski et al. (1991) reported various plant heights (11–37 cm) under different treatments, but they did not define compact; plants under 20 cm should be compact. The main concern in the present work was shoot length and branch number, as well as time to anthesis. When 0 LD to 10 LD cycles were applied, plant height remained compact but anthesis was delayed, while 30 LD and 0 SD to 15 SD cycles caused early anthesis with excessive shoot elongation. Previously, an LD treatment was found to decrease the time to anthesis but caused excessive shoot elongation with fewer lateral branches (Cathey and Piringier, 1961; Piringier and Cathey, 1960). The hypothesis behind this present work was that when

the plants received limited number of LD cycles, they would produce shorter but sufficient numbers of lateral branches. The length of the main stem and lateral branch was shorter when 10 LD or 15 LD cycles were applied, compared with most of the SD to LD treatments. The number of lateral branches in 15 LD cycles under TL was more than 6 and anthesis occurred 35.4 days after the start of treatment compared to 38.9 days in 10 LD cycles. Furthermore, petunia plants treated by 15 LD cycles under TL not only reached anthesis early, but they were compact and bushy.

The data reveal that the plant receiving the same number of photoperiodic cycles but exposed to different light quality behaved differently. Thus the main stem length between 0 SD treatments under TL or FL differed because the former emits more far-red radiation than does FL. Piringier and Stuart (1958), Tucker (1978), and Kasperbauer (1971) reported similar results for *Hydrangea macrophylla*, *Lycopersicon esculentum*, and *Nicotiana tobacum*, respectively. Therefore shoot development is not simply attributed to photoperiod, but to light quality as well.

To improve petunia plant shape and quality, with reasonable numbers of lateral branches and flowers opened, under insufficient light conditions, 15 LD cycles extended by TL is recommended. If the initial LD cycles are more than 15, excessive shoot elongation will occur. It should be noted, however, that this requirement, 15

LD cycles by TL, might depend upon other environmental factors such as temperature, or irradiance (Shimai, 1998). The difficulty of physiological study in petunia is that plants and cultivars behave differently under multi-environmental conditions.

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Literature Cited

- Adams, S. R., S. Peason, P. Hadley and W. M. Patefield. 1999. The effects of temperature and light integral on the phase of photoperiod sensitivity in *Petunia* × *hybrida*. *Ann. Bot.* 83: 263-269.
- Armitage, A. M. 1994. Ornamental Bedding Plants. p. 145-147. CAB International, Wallingford, Oxon, UK.
- Cathey, H. M. and A. A. Piringer. 1961. Relation of phosfon to photoperiod, kind of supplemental light, and night temperature on growth and flowering of garden annuals. *Proc. Amer. Soc. Hort. Sci.* 77: 608-619.
- Cooke, I. J. 1969. The influence of far-red light on the development of tomato seedlings. *J. Hort. Sci.* 44: 285-292.
- Kaczperski, M. P., W. H. Carlson and M. G. Karlsson. 1991.

- Growth and development of *Petunia* × *hybrida* as a function of temperature and irradiance. *J. Amer. Soc. Hort. Sci.* 116: 232-237.
- Kasperbauer, M. J. 1971. Spectral distribution of light in a tobacco canopy and effects of end-of-day light quality on growth and development. *Plant Physiol.* 47: 775-778.
- Piringer, A. A. and H. M. Cathey. 1960. Effect of photoperiod, kind of supplemental light and temperature on the growth and flowering of petunia plants. *Proc. Amer. Soc. Hort. Sci.* 76: 649-660.
- Piringer, A. A. and N. W. Stuart. 1958. Effect of supplemental light source and length of photoperiod on growth and flowering of hydrangeas in the greenhouse. *Proc. Amer. Soc. Hort. Sci.* 71: 579-584.
- Shimai, H. 1998. Environmental regulation of shoot development and flowering in petunia. Thesis. Univ. of Nottingham, Sutton Bonington, UK.
- Sink, K. C. 1984. Introduction-taxonomy. p. 1-9. In: Sink (ed.). *Petunia. Monographs on theoretical and applied genetics* 9. Springer-Verlag, Berlin.
- Tjia, B. 1981. Growth regulator studies on petunias. *Florist's Review* 167: 45-48.
- Tucker, D. J. 1976. Effects of far-red light on the hormonal control of side shoot growth in the tomato. *Ann. Bot.* 40: 1033-1042.
- Vince-Prue, D. 1977. Photocontrol of stem elongation in light-grown plants of *Fuchsia hybrida*. *Planta* 133: 149-156.

ペチュニアのシュート発達と開花に及ぼす光質と日長の影響

島井弘男

高森町立蘭植物園推進室 399-3101 長野県下伊那郡高森町山吹 2365

摘 要

ペチュニアのシュート発達と開花反応を調べるため、異なる日長と異なる光質を用いて処理した。ペチュニアを遠赤光に富む白熱灯または赤色光に富む蛍光灯で延長した長日から短日へ、或いはその逆へ移動する実験をおこなった。その結果、不十分な光条件下で、草丈が低く多数の花を咲かせる高品質のペチュニアを生産するためには、15日間の長日処理(8

時間の自然光に続いて8時間の白熱灯照射)を行ったのち、短日へ移動したものが最も有効であった。しかし、同じ長日処理を30日間おこなった場合はシュートが著しく伸長して商品価値を減じた。これらの結果から、ペチュニアの草姿は日長と光質を用いて改善されることが示唆された。