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***REFEREED MANUSCRIPT***

# EFFECTS OF LIGHT DURATION ON FLOWER DEVELOPMENT IN BLOOD LILY

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*Abstract.* **The responses of container-grown Blood Lily (*Scadoxus multiflorus* (Martyn) Raf.) to three light duration treatments were evaluated. Light duration treatments included exposure of plants to 8, 12, or 16 hours of light. The treatment consisting of 16 hours of light was the most effective in producing uniform floral development (time to anthesis and plant height). Therefore, long periods of light (long days) could possibly have a positive effect on Blood Lily uniform floral development based on the results obtained. The amount of light provided on average for 16 hours was similar to that provided for plants under 63% shade conditions (corresponding to an average of 29.95 mol m$^{-2}$ day$^{-1}$) in preliminary studies. Thus, Blood Lily could be commercially produced under partial shade in zones ranging from 9 to 11, and/or could be used as a landscape bedding plant. For northern areas below zone 9, Blood Lily could possibly be a good candidate for use as a cut flower and/or a potted plant. Further studies should address the factors involved in flower initiation, development and longevity, and subsequent plant performance, aiming the commercial production of Blood Lily.**

Blood Lily (*Scadoxus multiflorus* (Martyn) Raf.) is an evergreen bulbous monocotyledon in the Amaryllidaceae native to south tropical Africa (De Hertogh and Le Nard, 1993; Whistler, 2000). All nine species of *Scadoxus* used to be included in the genus *Haemanthus*, but now they are regarded as distinct. The showy red inflorescences are very attractive and the flowers are arranged in a dense umbel with up to 200 flowers (Friis and Nordal, 1976; Whistler, 2000). Blood Lily has been used as a landscape plant in North American gardens, ranging from Zones 9 to 11 (De Hertogh et al., 1990), but also with excellent performance in containers (Du Plessis and Duncan, 1989), and great potential for use as a cut flower (Koster, 1990).

Studies on the physiological factors that affect flowering in Blood Lily are very limited. Although some reports exist on flowering periods for several species of *Scadoxus*, most of the research has been conducted on *Scadoxus* × 'Konig Albert', a hybrid between *S. multiflorus* spp. *katherinae* and *S. puniceus* (De Hertogh and Le Nard, 1993). The only available study reports the influence of temperature on the vegetative and flo-

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ral development of *Haemanthus* × Hybridus 'Konig Albert' (Peters, 1974). Furthermore, there is a reported need for research on the effects of external factors on physiological processes in flowering bulbs in general, such as bulb formation and flower induction (Le Nard and De Hertogh, 2000).

It has been reported that floral initiation and progress to anthesis proceed at a rate determined by ambient temperature, the most influential determinant of flowering (Rees, 1992). However, there is no published information available on the responses of Blood Lilies to light duration, intensity or photosynthetic photon flux density (PPFD). A proper understanding of the effects of light on flowering of Blood Lilies could add valuable information for the commercial use of this species. The objective of this study was to evaluate the effects of light duration on flower development in Blood Lilies.

## Material and Methods

Sixty Blood Lily bulbs were obtained from a commercial grower (K. Van Bourgondien & Sons, Babylon, N.Y.). Each bulb was planted in a #1 (6 inches) plastic container filled with Fafard No. 2 potting substrate (Fafard Peat Moss, Anderson, S.C.). Containers were placed into three climatic Conviron S10H plant growth chambers with a CMP4030 microprocessor (Conviron LTD, Winnipeg, Manitoba, Canada). The bulbs were distributed into individual chambers (20 containers per chamber; one bulb per container) and calibrated with the respective settings: 8-h light (SD), 12-h light (LD1), and 16-h light (LD2). For all three chambers the same combination of incandescent and fluorescent lights were used to maintain an average light level of 525 μmol $m^{-2}$ $s^{-1}$ PPFD. Set point temperatures of 18 °C night and 25 °C day were maintained in the chambers, with relative humidity at 80%. All pots were watered daily using an automatic intermittent built-in microsprinkler irrigation system. Fertilization was not provided.

In preliminary studies, Blood Lilies were placed under four different light levels: full sun (FS), 30% shade (30S), 63% shade (63S), and 80% shade (80S). Environmental conditions, such as temperature and humidity were maintained at the same levels used for this study. Therefore, this study provided a continuation and complementation to the previous study.

Floral development was assessed using Stages IV and V for flowering, adapted from De Munk and Van der Hulst (1989), as follows: Stage IV – floral development and anthesis; Stage V – floral senescence and vegetative growth. For Stage IV, floral development was divided into three separate substages: a) floral bud visible, b) formation of spathe, and c) anthesis.

Flower uniformity was evaluated by the number of plants at the same stage of floral development for each treatment, plant height (cm), and time to anthesis (days). Plant height was evaluated using measurements from the base of the plant at the substrate level to the top of the umbel inflorescence. Time to anthesis was evaluated from the time of initial floral bud appearance (Stage IVa) to full opening of the inflorescence (Stage IVc). All observations were conducted over the flowering period for Blood Lily, from floral development through anthesis to senescence, under the conditions described above.

Analysis of Variance (SAS Institute, 1993) was conducted to determine if significant differences existed among the treatments and plant height. Significant differences between plant heights were calculated using standard errors (SE). The LSD procedure was performed to separate means among treatments where significant differences occurred ($P \leq 0.05$).

## Results and Discussion

General recommendations indicate that Blood Lilies should be grown under partial shade (Ellis, 2001), although with no accurate reference to the shade percentage or light intensity. However, it has been generally known that by altering light conditions, the performance of flower bulbs in containers and outdoor gardens can be enhanced (De Hertogh and Le Nard, 1993).

In preliminary studies, light intensity provided by 63% shade (29.95 mol $m^{-2}$ $day^{-1}$) resulted in better plant growth and uniformity. However, temperature and light can also influence significantly the timing of flowering, flower quality, stem length and strength in bulbs of *Sandersonia aurantiaca* (Catley et al., 2000). Temperature was not a variable in the current study and variations observed for the characteristics evaluated would likely be due to the light treatments. Results from the previous study involving light intensity are compared to light treatments in the current study and discussed further.

Floral development was observed among all treatments, although differences were observed in flowering uniformity, including plant height and time to anthesis. Figure 1 shows the different stages of floral development; Stage IVa – floral bud visible (Fig. 1A); Stage IVb – formation of spathe (Fig. 1B); Stage IVc – anthesis (Fig. 1C); and Stage V (floral senescence and vegetative growth (Fig. 1D).

The first signs of floral development with visible formation of floral bud (Stage IVa) were observed forty days after planting among all treatments. Fifty-four days after planting floral development and uniformity were evaluated. At this point plants were observed at different stages of floral development (IV through V) and some bulbs had already reached anthesis. The second data collection and evaluations were performed 77 days after planting, when most plants had reached anthesis.

Under SD (15.12 mol $m^{-2}$ $day^{-1}$), plant height averaged 23.4 ± 10.2 cm (Table 1) and 75% of bulbs expressed floral development (Stage IV) by day 54 (Fig. 2). However, floral development was non-uniform, with plants showing different floral development characteristics; 25% showing floral buds (Stage IVa), 30% showing spathe formation (Stage IVb) and 20% in anthesis (Stage IVc). Ten percent of the plants showed early floral senescence (Stage V), while 15% did not show any response. By day 77, 60% of all bulbs had reached anthesis moving through senescence, while 25% remained within Stage IV (Fig. 2). Despite the relatively high percentage of flowering at the end of the experiment, floral development was delayed compared to other treatments, while in some plants early floral senescence occurred, showing evident lack of uniformity. Overall, plants were shorter compared to other treatments. Similar results were obtained for plants growing under 30% shade in previous experiments (Table 1).

In contrast, although the great majority (95%) of bulbs in LD1 (22.68 mol $m^{-2}$ $day^{-1}$) were in Stage IV of floral development by day 54, only 25% had reached anthesis and irregular, non-uniform flowering was observed (Fig. 3). Fifty percent of bulbs showed a visible floral bud, while 20% showed formation of spathe. One bulb did not show any response. Plant height averaged 27.0 ± 6.5 cm (Table 1). Plant height and uni-

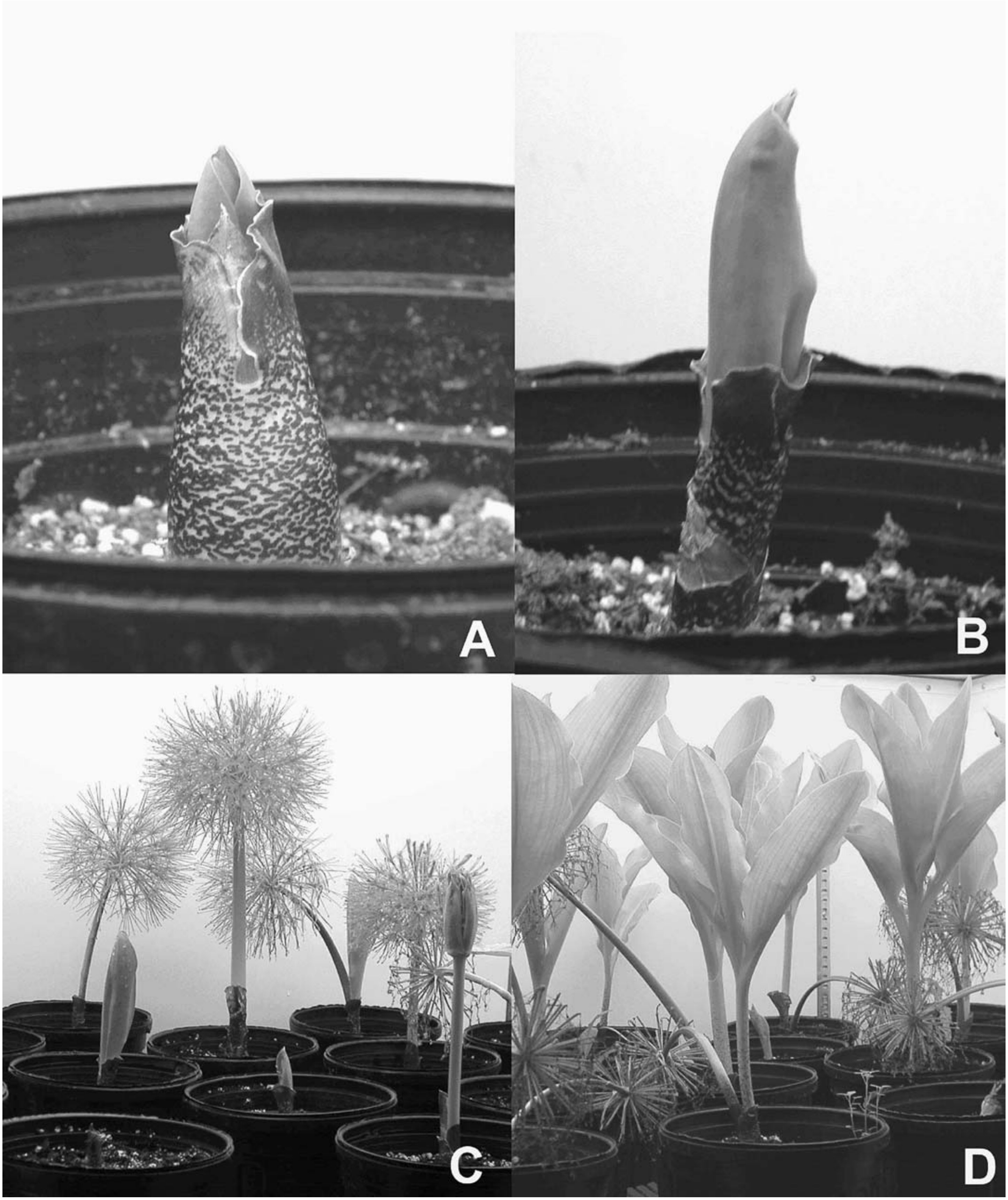


Fig. 1. Stages of floral development in Blood Lily: A. floral bud formation (Stage IVa); B. formation of spathe (Stage IVb); C. anthesis (Stage IVc); D. floral senescence and vegetative growth (Stage V).

Table 1. Height (mean ± SD) of Blood Lilies grown under different treatments: 8h-light (SD), 12-h light (LD1), 16-h light (LD2), full sun (FS), 30% shade (30S), 63% shade (63S), and 80% shade (80S).

| Treatment | Number of plants | Height (cm) |
|---|---|---|
| SD | 20 | 23.4 ± 10.2 d[z] |
| LD1 | 20 | 27.0 ± 6.5 cd |
| LD2 | 20 | 38.7 ± 1.7 a |
| FS | 12 | 31.0 ± 11.6 bc |
| 30S | 12 | 29.1 ± 10.0 cd |
| 63S | 12 | 38.3 ± 14.0 ab |
| 80S | 12 | 31.0 ± 12.0 bc |

[z]Means within a column followed by the same letters indicate no significant differences by LSD test, P≤ 0.05.

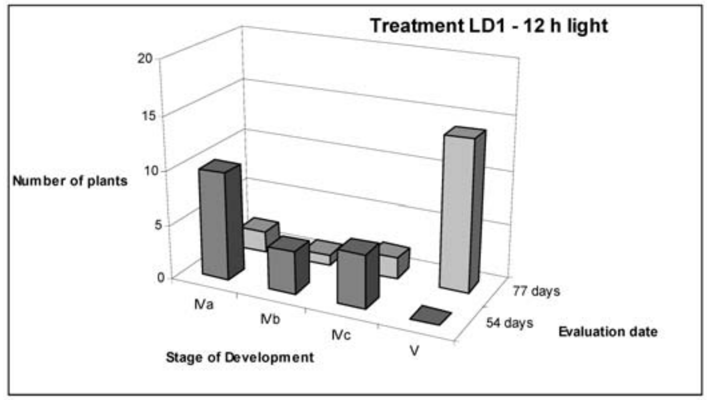


Fig. 3. Stage of floral development for Blood Lily plants under 12 hours of light (LD1) evaluated at 54 and 77 days after planting. Lack of uniformity is showed by the spread among different stages of floral development.

formity of floral development were intermediate between SD and LD2. No significant differences were observed in height for LD1 compared to SD or for 30% shade. However, height was significantly different for plants in LD2 ($P \leq 0.05$) compared to other treatments. Seventy percent of all plants had reached anthesis by the end of the experiment (Fig. 3).

For treatment LD2 (30.24 mol $m^{-2}$ $day^{-1}$), 100% of bulbs showed floral development (stage IV) at day 54 (Fig. 4). Although some bulbs were observed in different stages of development, only 1 bulb (5%) was still showing a visible bud and 2 bulbs (10%) had the spathe formed, while the majority (85%) had reached anthesis. The period of floral development varied from 35 to 40 days from planting. However, the bulb showing the floral bud did not progress to anthesis and somehow became arrested in development, while a second bulb still showed spathe formation with no anthesis. By the end of the experiment, 90% of the plants had reached anthesis (Fig. 4). Overall, the flowering bulbs were uniform in height, averaging 38.7 ± 1.7 cm, and showed bright green foliage (Table 1). At day 54, plant height differed among all treatments ($P \leq 0.05$). However, at day 77, plants in LD2 were significantly taller ($P \leq 0.05$), more vigorous, and uniform compared to the other treatments. These results were similar to those obtained for plants growing under 63% shade (Table 1). Blood Lilies grown under 63% shade (corresponding to an average of 29.95 mol $m^{-2}$ $day^{-1}$) showed better overall floral development and uniformity compared to plants grown under 30% shade, 80% shade or full sun.

Overall, for all treatments floral development was observed within 5 weeks, with flowering peaks varying from 8 to 10 weeks, and floral development completed by week 12. However, flower longevity was limited to 7 d, which could be a limitation for use of Blood Lily as a potted plant. Knowledge and control of all factors involved in flowering is essential for efficient flower production (De Vroomen, 1993), therefore the factors that affect flower longevity should be further investigated.

In this study, manipulation of light duration provides a means to elucidate and therefore enhance floral development in Blood Lily. In general, from previous experiments, it was found that bulbs planted under 63% shade, 80% relative humidity, and 18 °C night/25 °C day temperature in Southern Florida will produce uniform floral development. Likewise, similar light levels (LD2) in the current study would result in plants that are uniform in size and timing to anthesis. Treatment LD2 was the most efficient in producing uniform floral development (time to anthesis) and was comparable to 63% shade conditions.

Long days may have had a positive effect on Blood Lily uniform floral development based on the results obtained. However, in this study photoperiod was not considered a factor, since plants under LD1 and LD2 received higher light intensity compared to SD. Understanding the effects of

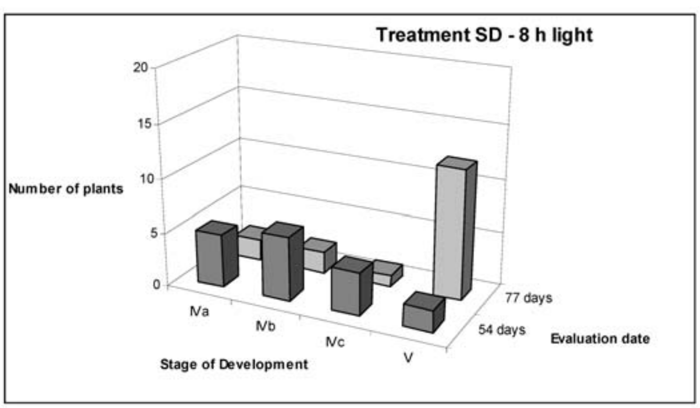


Fig. 2. Stage of floral development for Blood Lily plants under 8 hours of light (SD) evaluated at 54 and 77 days after planting. Lack of uniformity is showed by the spread among different stages of floral development.

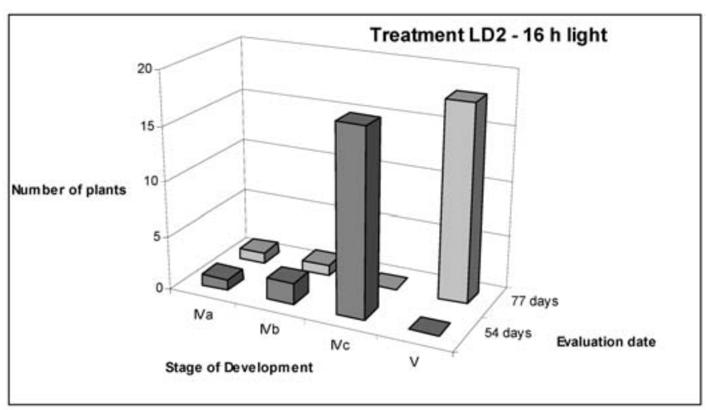


Fig. 4. Stage of floral development for Blood Lily plants under 16 hours of light (LD2) evaluated at 54 and 77 days after planting. Most plants had reached anthesis (Stage IVc) by day 54 and senescence (Stage V) by day 77, showing uniform floral development.

external factors on physiological processes like flowering is an essential component of research for the commercial use of any species (Le Nard and De Hertogh, 2000). Therefore, the future elucidation of flowering responses to daylength differences in Blood Lily is necessary and could provide growers with useful information to time crop production.

Plant height under LD2 was significantly different from the other treatments. This information could be relevant when considering Blood Lily as a cut flower, since longer flower stalks would provide a more attractive flower. However, height could be a constraint for commercialization of potted Blood Lilies, where shorter plants would have a better market value. By manipulating light intensity, duration, and photoperiod, plant size could be controlled for cultivation of Blood Lily as a potted plant.

Therefore, for Florida conditions ranging from zones 9 to 11 and provided that the plants are partially shaded (about 60% shade), Blood Lily would be an excellent candidate for nursery commercial production. Likewise, the same parameters could apply for use of Blood Lily as a bedding plant. In fact, Blood Lilies have been successfully cultivated in the landscape in Miami, Fla., under partial shade (Michael Maunder, Fairchild Tropical Garden, personal communication).

For northern areas below zone 9, Blood Lily would probably be a good candidate for use as a cut flower and/or a potted plant. However, the short-lived flower limits the plant use as a cut flower and additional studies are necessary to address and/or promote flower longevity. Yet, the perennial characteristic of this species and the attractive foliage make it an enjoyable container ornamental year-round.

Further studies should address the factors involved in flower initiation, development and subsequent plant performance, aiming the commercial production of Blood Lily.

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