# Quality of Supplemental Lighting and Bulb Planting Depth on Development of Naturally Cooled *Lilium longiflorum* Thunb. 'Harson'[1,2]

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*Abstract.* Four-hour dark period interruptions of incandescent, red and far-red radiation each night during natural cooling hastened flowering by 22, 15 and 8 days, respectively, over natural daylengths. No additional acceleration occurred when night breaks were applied during natural cooling and forcing as compared to lighting during natural cooling only. The accelerating effect of night breaks was found to be the response to light alone and not total radiant energy or temperature. Bloom date acceleration by night breaks of incandescent light was due to a proportionate acceleration in flower bud initiation. For every week of acceleration there was an average decrease of 2 flower buds and 7 leaves per stem. Bulb potting depth also influenced bloom date. The depth effects on flowering time were independent of lighting treatments. A 4-day acceleration was obtained by setting the bulb nose at the soil line as compared to a 2 inch planting depth.

Plant height was independently influenced by photoperiod-light quality and by potting depth. Height was only slightly affected by supplemental lighting during natural cooling. After forcing temperatures were reached, red and incandescent lighting caused slight height increases while far-red caused pronounced stem stretching. Exposure of the bulb above the soil at potting reduced plant height at maturity.

## Introduction

Recent studies have shown that flowering of the Easter lily, *Lilium longiflorum* Thunb., can be accelerated by long days (3, 11, 12) and that noncooled or partially precooled bulbs appear to be more responsive to photoacceleration than fully precooled bulbs. The effect of supplemental lighting on flowering time appears most pronounced at temperatures below the forcing temperature range.

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Waters and Wilkins (12) hastened flower bud differentiation and flowering by as much as 8 weeks in uncooled 'Georgia' Easter lilies by lighting rosetted plants which were exposed to natural cooling conditions. They recorded a maximum effect from a 3- to 5-hr light break of 8–16 ft-c of incandescent light in the middle of the dark period for 30 consecutive nights. Gill and Stuart (3) supplied radiation from a 250 w infrared brooder lamp as a 4-hr light break for 4 weeks during natural cooling and achieved a 10 day acceleration in the same cultivar. The early flowering resulted in a slight reduction of flower buds and leaves per plant. Roberts and Blaney (8) have recently reported that 'Croft' bulbs which received insufficient vernalization stimulus required long days for floral induction and initiation to occur.

Other cultural studies appear to implicate light as an important factor at the time of bulb planting. Box (1) found that mulches delayed sprout emergence from the soil as compared to unmulched pots of 'Harson' lilies. No differences existed in soil moisture or temperature between the early and later sprouting groups (unpublished data). Miller et al. (6) found that exposing a portion of the bulb above the soil hastened blooming of precooled 'Ace' by about 2 weeks as compared to bulbs set 2 inches deep.

This study was conducted to determine the influence of the quality of supplemental lighting on the development of the lily and to evaluate the effects of bulb planting depth in combination with daylength and light quality.

## Materials and Methods

Bulbs (5–6 inches) of the 'Harson' lily, *Lilium longiflorum,* Thunb., were potted on September 1, 1967 in 6 inch clay pots. Similar lots of the bulbs were set at the following potting depth: 1) the nose of the bulb 2 inches below the soil surface (commercial potting depth), 2) the nose at the soil line, and 3) half of the bulb mass exposed above the soil. All pots were placed on the raised center bench of an uncovered plastic greenhouse for daylength-light quality control while receiving natural cooling.

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development of the ovary wall near the base of the style. The cold temperature may have inhibited either the formation or prevented the transport of important growth substances necessary for normal cell division near the base of the style and, therefore, complete closure of the carpels was not accomplished (Fig. 3).

Susceptibility to the catfacing deformity appears to be hereditary. Breeding lines and varieties of tomato differ in their sensitivity to cold temperatures during the seedling stage and should be evaluated for this character, since they may carry genes that ultimately could express their influence in the formation of abnormal fruits. The tomato breeder needs to subject segregating plant populations to a low temperature seedling screening test to eliminate susceptible geneotypes.

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Four daylength-light quality control conditions were set up. The natural seasonal daylength (ND) was supplemented in 3 treatments by 4-hr dark period interruptions of far-red, red and incandescent light from 10 PM to 2 AM each night. The incandescent light was supplied by a 40 w lamp which provided an average visible intensity of 13 ft-c at plant level over the entire illuminated area. The average radiant energy recorded for all wave lengths between 3800 Å and 11000 Å was 8.84 $\mu w/cm^2$ (microwatts per square centimeter). Red light was obtained by filtering the light from a 20 w cool white fluorescent lamp through 2 layers of red cellophane. This provided a 1000 Å band width with a radiation maximum of 6750 Å. The average energy level was 0.24 $\mu w/cm^2$. Far-red was obtained by filtering out all radiation below 7000 Å from a 200 w incandescent source with a commercial far-red filter.[5] The far-red produced an average energy level of 19.98 $\mu w/cm^2$ from 7000–11000 Å and produced a slight temperature increase. The increase, however, never exceeded 1° F at plant level. Total radiant energy levels were measured with an ISCO Model SR Spectroradiometer.[6] The primary considerations in setting up the supplemental light sources were to obtain definite wave length band limits and minimize temperature differences. Visible energy levels were kept low enough to keep light absorption by chlorophyll minimal.

The natural seasonal daylengths (hours and minutes) for State College, Mississippi were: September 12 – 21, October 11 – 28, November 10 – 39, December 10 – 14, January 10 – 25, February 11 – 07, March 11 – 58, April 12 – 25.

The greenhouse bench was divided into 8 compartments with curtains of black polyethylene film on all sides. The top of each compartment was open to accommodate the lamps for the lighted treatments and to allow natural temperatures to prevail. The curtains were lowered after sunset to form the compartments and raised at sunrise. The lamps were suspended from the top of the greenhouse and were periodically adjusted so that the light source was always 24 inches from the tops of the plants. Twenty pots of each planting depth were placed in every compartment in 4, 3 × 3 latin squares. An additional sample row of 6 pots was placed at each side of the latin square arrangement. Each photoperiod-light quality treatment was replicated twice. The average monthly high and low temperatures during the period of natural cooling were: September 79 – 59, October 75 – 49, November 63 – 39, December 57 – 40.

Forcing was begun on January 1, 1968 by covering the plastic greenhouse with 4 mil polyethylene and adjusting the temperature at 50° for 2 weeks and then raising it to 60° for the remainder of the growing period. At the start of forcing, half of the pots were removed from each photoperiod-light quality compartment and placed on a side bench in the same greenhouse to be forced under natural light conditions. These plants were arranged in a randomized complete block design of 2 pots per treatment in 6 replicates. The data from these plants were analyzed as a 4 × 3 factorial (light × depth). The pots remaining in each lighting compartment received photoperiod-light quality control until the first bloom opened on all plants in the plot. Data from these plants were analyzed as a randomized complete block using light conditions over all planting depths as treatments.

Stem apices of sample plants were prepared for microscopic study at 14-day intervals from December 1 until flower buds were visible. The material was killed and fixed in FAA (90 ml 50% ethanol, 5 ml acetic acid, 5 ml formalin) and slides were prepared by the paraffin method outlined by Sass (9). Sections were cut to 10 microns and stained with a triple stain as described by Popham and Johnson (7).

At anthesis the following data were recorded: date of first bloom, leaf and flower bud number, and plant height from the pot rim to the bend of the uppermost flower peduncle.

[5]Manufactured by West Lake Plastic Co., Lenni Mills, Pa., under the designation FRF 700.

[6]Instrument Specialties Co., Inc., Lincoln, Nebraska.

## Results and Discussion

Levels of significance for the effects of the factors studied during the period of natural cooling are shown in Table 1.

*Table 1.* Significance levels (Fisher's F test) of the factors studied on development of naturally cooled pot, 'Harson' lilies.

| Factor evaluated | Time of shoot emergence | Forcing time | Bud number | Plant height | Leaf number |
|---|---|---|---|---|---|
| Photoperiod-light quality treatment | NS | ** | ** | ** | ** |
| Bulb potting depth | ** | * | NS | ** | NS |
| Photoperiod-light quality × depth | * | NS | NS | NS | ** |

*.05.
**.01.
NS non-significant.

*Sprout emergence.* The criterion for sprout emergence was the time at which the sprout was visible from the top of the bulb in the exposed bulb treatment and when the sprout broke the soil in the case of the deeper plantings. Emergence time was directly proportional to bulb depth. An obvious factor contributing to this was the distance the sprout had to grow through the soil in the deep planting. Supplemental lighting with the light qualities used, had no effect on the time of sprout emergence when compared to natural daylengths. An interaction occurred, however, between light and depth treatments. Exposure of the bulb coupled with an incandescent light break caused earliest sprouting (16 days after potting). The longest emergence time (34 days) was recorded for the deepest bulb setting under natural daylengths. There was no correlation between sprouting time and days to flower with the treatments of this study.

*Days to flower.* Four-hour dark period interruptions of incandescent, red and far-red each night during the natural cooling period hastened blooming by 22, 15 and 8 days, respectively, over natural daylengths (Table 2). The comparative rates of development at the time the first treatment flowered are shown in Fig. 1. These effects were independent of potting depth and no additional acceleration was achieved by continuation of lighting

*Table 2.* Effects of quality and time of application of 4-hr light breaks on development of naturally cooled pot 'Harson' lilies.

| Lighting treatment | Forcing time (days) | Flower buds (per stem) | Plant height (inches) |
|---|---|---|---|
| *Natural cooling* | | | |
| Natural days (ND) | 88.1 a[x] | 12.4 a | 19.5 ab |
| ND + Far-red | 80.2 b | 10.0 b | 20.3 a |
| ND + Red | 72.7 c | 7.7 c | 19.0 b |
| ND + Incandescent | 66.4 d | 6.2 d | 17.2 c |
| *Natural cooling and forcing* | | | |
| Natural days (ND) | 88.1 m | 11.8 m | 21.4 m |
| ND + Far-red | 81.0 n | 9.4 mn | 32.7 n |
| ND + Red | 71.2 o | 7.6 n | 24.0 o |
| ND + Incandescent | 64.9 p | 6.6 n | 24.9 o |

[x]Within columns and sets, means followed by the same letter are not significantly different at the 5% level.



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after forcing temperatures were reached (Table 2). These results reflect the findings of Waters and Wilkins (12) that non-precooled lily plants were most responsive to photoinduction of flowering from November 1 to January 1 following a September planting.

This study clearly demonstrates that the observed acceleration of flowering by supplemental lighting is the effect of visible radiation alone and not the total radiant energy level. The plants responded as long day plants to extended photoperiods during natural cooling. The observed flowering response to light quality suggested activity by the phytochrome controlled red, far-red light system. The acceleration of blooming caused by the incandescent and red light may have been due to an active level of the $P_{fr}$ form of the phytochrome pigment maintained over a long period of time each day in response to red radiation. The greater response to incandescent light may be accounted for by more red energy from the incandescent source than from the pure red (2.96 and 0.24 $\mu w/cm^2$, respectively). Such a scheme would agree with a model of phytochrome action proposed by Lane et al. (5). The significant acceleration by night breaks of far-red could have resulted from the constant low level of active phytochrome present in far-red light (10). Koukkari and Hillman (4) have found high phytocrome levels in flower buds of *Lilium superbum*. It is obvious, however,

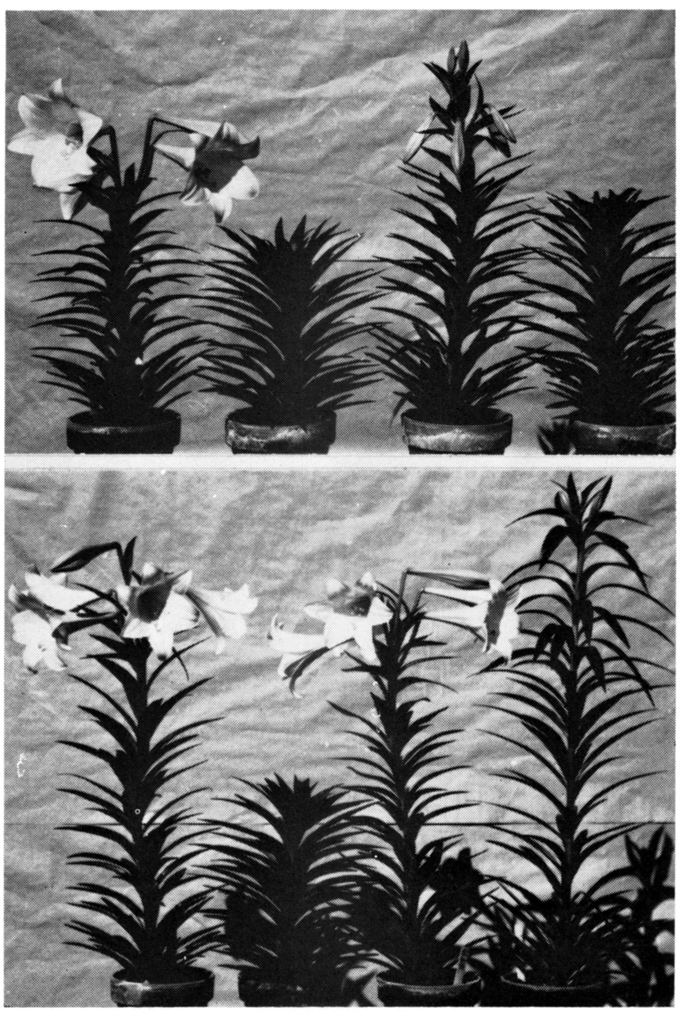

*Fig. 1.* 'Harson' lily plants subjected to photoperiod-light quality treatments during natural cooling (top) and during natural cooling and forcing. Left to right: incandescent, ND, red, far-red. Photographed 60 days after start of forcing.

that additional investigations are needed for conclusive evidence of the activity of phytochrome in the light acceleration of lily flowering.

Bulb planting depth also affected forcing time as shown in Table 3. Flowering was accelerated 4 days when bulbs were planted with tips at the soil line as compared to those planted deeper.

*Table 3.* Effects of bulb planting depth on development of naturally cooled pot 'Harson' lilies.

| Planting depth | Forcing time (days) | Flower buds (per stem) | Plant height (inches) |
|---|---|---|---|
| Bulb 2" deep | 79.10 a[x] | 8.72 a | 20.18 a |
| Nose at soil line | 75.27 b | 9.30 a | 19.10 a |
| ½ bulb exposed | 76.20 ab | 9.25 a | 17.66 b |

[x]Means in any one column with the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

*Flower bud initiation.* Microscopic evidence of floral initiation was seen on December 15, 2 weeks before the start of forcing, on plants under night breaks of incandescent light at all potting depths. All other treatments were still vegetative (Fig. 2). Box (2) has reported that flower bud initiation normally occurs in naturally cooled 'Harson' lilies about 2 to 3 weeks after the start of forcing temperatures. This timing was confirmed by this experiment since flower initiation was observed under all other treatments on January 15. It is probable that there were differences in time of flower bud initiation between plants of the red and far-red treatments but that they were not detected because of the 2-week sampling interval. Bulb depth had no measurable influence on the time of initiation.

*Flower number.* For every week of floral acceleration resulting from supplemental lighting during natural cooling there was an approximate decrease of 2 flowers

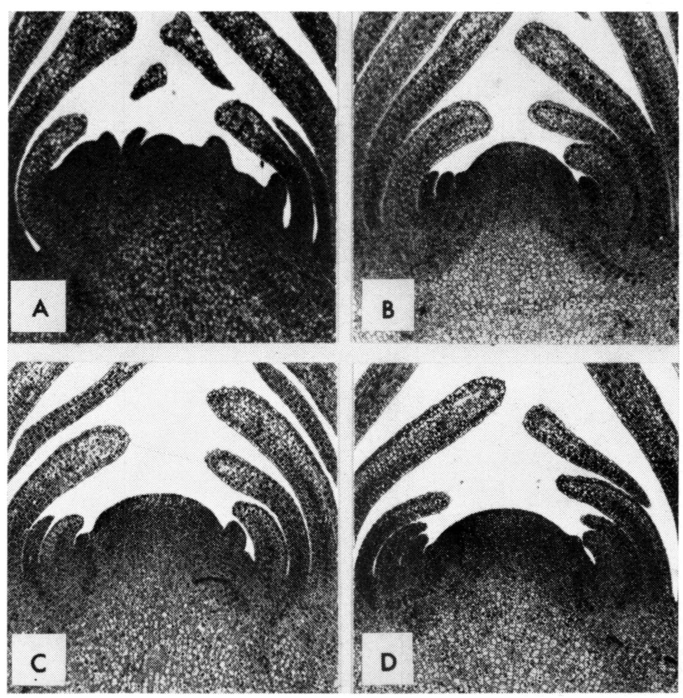


*Fig. 2.* Comparison of stem apices on December 15. Plants were naturally cooled under: A–incandescent, B–ND, C–red, D–far-red. × 20. Evidence of the reproductive condition is seen in photomicrograph A by the presence of flower bud primordia. The other apices (B, C, D) show the typical vegetative configuration of the smooth meristematic dome.



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per stem. Lighting during forcing, regardless of the quality of the light break had relatively little effect on bud count (Table 2). Potting depth had no effect on flower number (Table 3).

*Leaf number.* Leaf number was influenced by lighting treatment and by an interaction between light and bulb depth. Night breaks reduced leaf number by as much as 21 leaves depending upon the quality of the light (Table 4). Leaf number was directly proportional to days to

*Table 4.* Effects of the quality of light breaks during natural cooling and bulb depth on leaf number of pot 'Harson' lilies.

| Lighting treatment | Number of leaves formed | | |
|---|---|---|---|
| | Tip of bulb 2" deep | Tip of bulb at soil line | ½ of bulb exposed |
| Natural days (ND) | 89.0 bc[x] | 105.8 a | 96.4 b |
| ND + Far-red | 89.0 bc | 91.6 b | 91.4 b |
| ND + Red | 74.4 de | 81.8 cd | 80.6 cd |
| ND + Incandescent | 79.8 de | 71.0 e | 70.4 e |

[x]Any means with the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

flower and bud number. This relationship was also noted by other workers (3, 8). It suggests that bloom acceleration caused by long days requires a growth substrate which under periods of slower development would be used for increased leaf and bud formation. Any photosynthetic increase as a result of increased leaf number was not, however, reflected in plant dry weight or leaf chlorophyll at or prior to the period of light effect.

*Plant height.* Photoperiod-light quality treatments during natural cooling had only a slight influence on plant height. After forcing temperatures were reached, height was dramatically affected by daylengths and quality (Table 2). Plants grown under night breaks of far-red during forcing were 7–8 inches taller than those under incandescent or red light. Bulb planting depth influenced plant height independently of light (Table 3). Deep plantings increased plant quality by increasing stem rooting and plant anchorage.

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