Controlled Temperature Forcing of Planted Lily Bulbs[1]

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Abstract. The effects of a 63° period of development prior to cooling on the forcing of *Lilium longiflorum* were compared with precooling treatments. Different bulb sizes of 'Ace' and 'Nellie White' lilies were used. It was found that a growing period at 63° prior to cooling significantly increased the number of leaves and floral buds. It had no consistent effect on the number of days to flower or final plant height.

With the 'Ace' lily, the greatest number of floral buds was observed with a treatment of 3 weeks at 63° followed by 5 weeks at 38°. Within a single bulb size, the 'Ace' lily produced more floral buds, was a taller plant, and had more leaves than 'Nellie White'. The number of leaves and floral buds increased with an increase in bulb size regardless of the type of low temperature treatment or cultivar used.

Introduction

The growth and development of *Lilium longiflorum* Thunb. is controlled by many environmental factors (11). Stuart (21) has demonstrated that moisture and temperature are 2 of the most important factors. At present, lily bulbs are prepared for forcing either by precooling them in moist peat for at least 5 weeks (8, 22) or by potting the bulbs on arrival and then naturally cooling them (3, 4, 7, 16). It has been shown (3, 4) that naturally cooled lilies have a higher bud count and more leaves than precooled lilies. Also, the lower leaves are longer. Commercially, therefore, a more desirable plant is produced. Thus, forcing is a compromise between speed, number of flowers and number and length of the leaves.

Since natural cooling is dependent on the prevailing weather conditions, the method has inherent limitations from year to year and from location to location. Previous studies by Stuart (20) and Merritt (14) have indicated that controlled temperature cooling of planted bulbs may be a solution to the problem of forcing Easter lilies. The objective of this study was to evaluate the effects of various periods of controlled growth prior to cooling on the development of planted lily bulbs. A preliminary report has been published (6) and this procedure has been termed controlled temperature forcing (CTF).

Materials and Methods

The bulbs, *Lilium longiflorum* Thunb. cv. 'Ace' and 'Nellie White', were grown at a single location in Smith River, California. They were harvested and transported under normal conditions to the United Bulb Co., Mt. Clemens, Michigan. On arrival, the bulbs were placed at 63° F until taken to East Lansing.

All bulbs were planted in a soil mixture of sandy loam, peat, and 'Turface' (2:1:1). The bulbs were planted approximately ½ inch from the bottom of the pot in order to develop stem roots as well as basal roots (Fig. 5). After planting they were drenched with a solution containing 35% 'Dexon' and 75% 'Terraclor' (8 and 4 oz. per 100 gal, respectively). Monthly applications of 'Dexon' were used. All bulbs were watered as needed to maintain adequate moisture. In the greenhouse, all treatments were fertilized at every third watering with a solution of 2½ lb. of 25-0-25 and ½ oz. of a commercial trace element mixture per 100 gal of water.

Experiment 1. This experiment was carried out during the 1966–67 forcing season. A description of the treatments is presented in Table 1. A split plot design was used with each treatment being the top-split and consisting of 4 replications per bulb size with 4 observations per replication. All plants were placed in a 62–70° night-day greenhouse on December 14, 1966.

Table 1. Description of treatments for Experiment 1, 1966–67. 6½ to 7 and 7 to 8 inch 'Ace' lilies were used.[a]

Treatment number	Type of temperature treatment (°F)
1	Precooled in moist peat for 8 weeks at 38°
2	Precooled in moist peat for 8 weeks at 48°
3	Potted directly, rooted for 1 week at 63° followed by 38° for 7 weeks
4	Potted directly, rooted for 2 weeks at 63° followed by 38° for 6 weeks
5	Potted directly, rooted for 3 weeks at 63° followed by 38° for 5 weeks
6	Potted directly, rooted for 1 week at 63° followed by 48° for 7 weeks
7	Potted directly, rooted for 2 weeks at 63° followed by 48° for 6 weeks
8	Potted directly, rooted for 3 weeks at 63° followed by 48° for 5 weeks

[a]All rooting and low temperature treatments were initiated on October 19, 1966 and terminated on December 14, 1966.

Experiment 2. This experiment was carried out during the 1967–68 forcing season. A description of the treatments is presented in Table 2. A 2 × 2 × 2 factorial design was used with each treatment consisting of 4 replications with 6 observations per replication. All treatments were placed in a 62–70° night-day temperature on December 29, 1967.

Data recorded. The number of days to flower was calculated from the date on which the plants were carried into the greenhouse until the date that the first flower opened. The total number of floral buds included all the buds which were visible on the date the first flower opened. Plant height was measured as the distance from soil level to the highest portion of the plant. The number of leaves counted included all the leaves and visible leaf scars from soil level to the base of the pedicel of the lowest flower.

Results

Experiment 1. The data obtained in this experiment are presented in Table 3. A comparison of the CTF

Table 2. Description of treatments for Experiment 2, 1967–68.[a]

Treatment number	Cultivar	Bulb size (inches)	Type of temperature treatment (°F)
1	Ace	7 to 8	Potted directly, rooted for 3 weeks at 63° followed by 35° for 5 weeks
2	Ace	8 to 9	Potted directly, rooted for 3 weeks at 63° followed by 35° for 5 weeks
3	Nellie White	7 to 8	Potted directly, rooted for 3 weeks at 63° followed by 35° for 5 weeks
4	Nellie White	8 to 9	Potted directly, rooted for 3 weeks at 63° followed by 35° for 5 weeks
5	Ace	7 to 8	Precooled in moist peat at 35° for 8 weeks
6	Ace	8 to 9	Precooled in moist peat at 35° for 8 weeks
7	Nellie White	7 to 8	Precooled in moist peat at 35° for 8 weeks
8	Nellie White	8 to 9	Precooled in moist peat at 35° for 8 weeks

[a]All rooting and low temperature treatments were initiated on November 3, 1967 and terminated on December 29, 1967.

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treatments with precooling treatments over both bulb sizes showed that there was no significant difference in the number of days to flower. We found, however, that regardless of the type of treatment that the 48° treatments always flowered earlier than bulbs cooled at 38°. Within the CTF treatments, no differences were found within the 48 or 38° treatments. Thus, the varying lengths of low temperature cooling which were used in combination with the 63° treatments did not have a significant effect on the number of days to flower.

The CTF treatments always produced a greater number of floral buds than the precooling treatments regardless of the temperature utilized (Table 3). When the 2 precooling treatments were compared no significant differences were found between 38 and 48° F. Within the CTF treatments, however, there was a significant increase in the number of buds on plants cooled at 38° compared to those cooled at 48°. This indicates that the degree of cold effected the different number of floral buds and that the low temperature treatment was more critical for CTF bulbs than for precooled bulbs. Among the CTF treatments which were cooled at 38°, no significant differences were observed. There was, however, a trend towards a higher number of floral buds with a reduced period of cold. A similar analysis of the CTF treatments at 48° revealed that treatment 7 produced a significantly higher number of buds than either treatment 6 or 8. Thus, it was concluded that bulbs which are given a low temperature treatment after a 63° growth period produce a significantly higher number of floral buds than precooled bulbs. Also, that the 'Ace' lily is more responsive to 38° than to 48°. Note, however, that both the number of floral buds and days to flower are increased with the 38° treatments.

Total plant height was also influenced by the method of application of the low temperature treatment (Table 3). The data show that precooled 'Ace' lilies were taller than CTF bulbs. This was not observed in Experiment 2. No significant difference was observed between the 2 precooling temperatures nor was there differences between the CTF treatments at 38° F. At 48°, treatment 6 produced slightly taller plants than either treatment 7 or 8. Thus, plant height appears to be influenced to a lesser degree by the specific low temperature treatments than either the number of floral buds or the number of days to flower.

It was found that 6½ to 7 inch bulbs required longer to force than 7 to 8 inch (Table 3). This was particularly true with the CTF method of cooling at either 38 or 48°. Also, 7 to 8 inch 'Ace' lilies always produced more floral buds and were taller plants than 6½ to 7 'Ace' lilies.

Experiment 2. During the forcing season of 1967–68 the CTF and precooling methods were again compared.

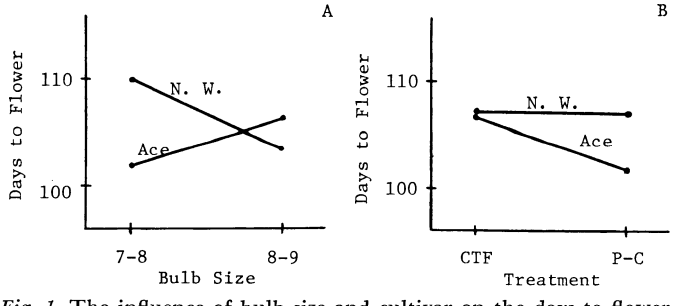

Fig. 1. The influence of bulb size and cultivar on the days to flower of 'Ace' and 'Nellie White' lilies. CTF treatment was 3 weeks 63° followed by 35° for 5 weeks, precooling (P-C) treatment was 8 weeks at 35°.

The data were subjected to an analysis of variance and the important interactions are presented in Fig. 1 to 4.

'Ace' requires fewer days to flower than 'Nellie White' (Fig. 1B). In addition, the various bulb sizes respond differently with respect to the number of days to flower (Fig. 1A). A highly significant difference was found between CTF and precooled methods. Precooled lilies forced quicker than CTF lilies. This was not observed in Experiment 1 (Table 3). The interactions reveal that with an increase in bulb size, 'Nellie White' requires less time to force than 'Ace'. On the other hand, 'Ace' responded quicker to the precooling treatment of 35° F than 'Nellie White' (Fig. 1B). It appears that this response was dominated by the 7 to 8 inch 'Ace' and not the 8 to 9 inch bulbs (Fig. 2). With 'Nellie White' there was very little difference between the 2 treatments and the bulb sizes (Fig. 2). It was concluded that the treatment required to program a specific cultivar and bulb size will be different.

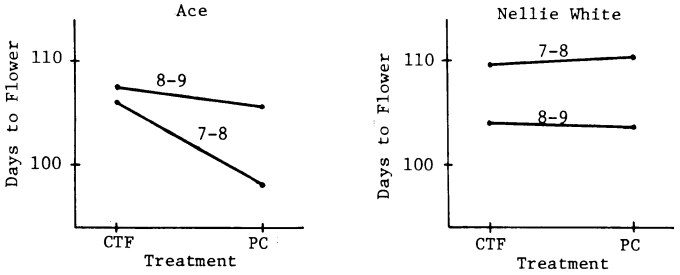

Fig. 2. The interaction between bulb size and low temperature treatments on the days to flower of 'Ace' and 'Nellie White' lilies. Treatments same as Fig. 1.

In 1967–68, as in 1966–67, the most striking response of the CTF treatment in comparison with the precooled bulbs was the increase in the number of floral buds (Fig. 3). Both 'Ace' and 'Nellie White' produced more floral buds with each increase in bulb size. In addition, 'Ace' always produced more flowers than 'Nellie White'. Fig. 3A illustrates that when the bulb size was increased from 7 to 8 inch to 8 to 9 inch, 'Nellie White' responded more than 'Ace'.

'Ace' lilies are taller than 'Nellie White' regardless of bulb size (Fig. 4). In addition, with an increase in bulb size, the 'Ace' lilies increased in height more than 'Nellie White'. There were no differences between the 2 types of low temperature treatments. Thus, we concluded that plant height is predominantly controlled by the cultivar and the specific bulb size with the low temperature treatment having little or no effect. It should be noted, however, that environmental factors, such as photoperiod (19) and the fertilizer regime (24) can effect plant height in lilies.

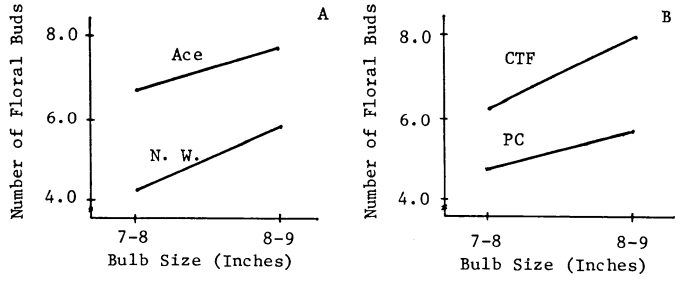

Fig. 3. The effect of bulb size and low temperature treatment on the number of floral buds of 'Ace' and 'Nellie White' lilies. Treatments the same as Fig. 1.

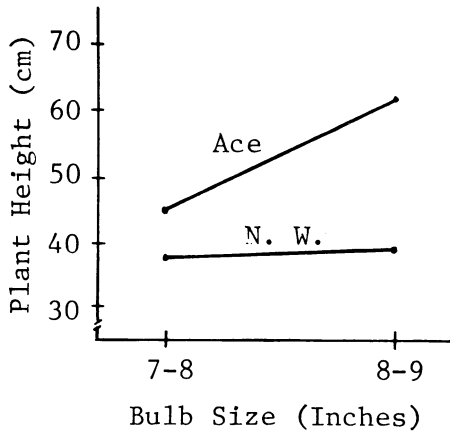

Fig. 4. The interaction between different bulb sizes of 'Ace' and 'Nellie White' lilies on plant height.

Recently, much attention has been given to the number of leaves which develop during forcing (2). Significant differences were observed between 'Ace' and 'Nellie White' lilies, the 'Ace' lily having more leaves. Also, with the increased bulb size with 'Ace' a significant increase in the number of leaves was observed. 'Nellie White' did not respond accordingly. The CTF method produced more leaves per plant than the precooling method. The 7 to 8 inch 'Ace' lilies averaged 80 and 97 leaves for the precooling and CTF method, respectively. With 7 to 8 inch 'Nellie White' there were 58 and 67 leaves for the precooling and CTF methods, respectively. Similar results were obtained with the larger bulb size.

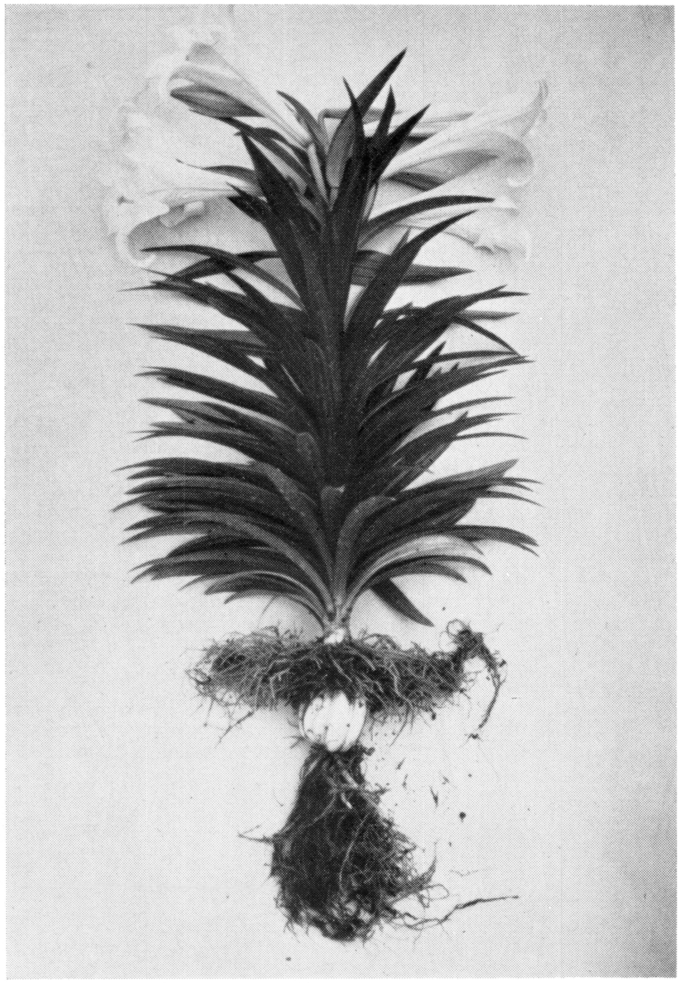

Fig. 5. An illustration of stem roots and leaf arrangement of 7 to 8 inch 'Ace' lily forced using CTF method.

Table 3. Treatment means of data recorded for Experiment 1, 1966–67.

Cultivar and bulb size	Treat. no.	Days to flower	No. of buds	Plant height (cm)
Ace, 6½ to 7.....	1	110	3.8	42
	2	103	3.7	40
	3	113	4.5	40
	4	110	5.1	42
	5	112	5.3	38
	6	104	4.3	38
	7	109	4.6	37
	8	105	4.4	32
Ace, 7 to 8.....	1	109	4.8	50
	2	100	5.9	56
	3	105	7.8	50
	4	104	7.8	50
	5	103	8.2	50
	6	98	7.3	54
	7	97	7.6	49
	8	100	6.4	49
Error mean square		30.17	1.51	20.14

Discussion

The data (Table 3, Fig. 3) show that the CTF method of forcing lilies produces a marked increase in the number of floral buds when compared with the precooling method. Both 'Ace' and 'Nellie White' showed an increase in the number of buds (Fig. 3). Wilkins and Widmer (25) have reported similar results with 'Nellie White' using a 60° growth period. All bulb sizes tested thus far produced similar responses (Table 3, Fig. 3). This appears to be the most important effect since other parameters such as days to flower and plant height can be influenced by other environmental conditions (12, 19, 24). This increase is in agreement with the reports by Box (3), Payne (16), and Stuart and Doucette (23) that during natural cooling lilies show an increased bud count. Preheating of lilies at some temperature between 60° and 70° F prior to either precooling or natural cooling has also been reported to conserve the number of floral buds produced (1, 15, 23). There is no direct evidence to indicate why this phenomena occurs but at least 2 possibilities exist.

The rooting of bulbs either during or prior to the application of a low temperature treatment may preserve the capacity of the plant to produce a large number of floral buds. This is a distinct possibility since it is well known that lilies grown continuously in a 60° greenhouse will produce a large number of floral buds (1, 15). Perhaps, the preservation is due to the synthesis of some material(s) in the bulb scales during the 60–65° treatment and that these are subsequently transported to the apex.

Alternatively, the growing period may in some way increase the responsiveness of the plant to the low temperature stimulus. This may result in a larger apex. Kohl (13) has shown that the larger the apex the greater the number of leaves which can be observed. Also, he found that the apex diameter increases with bulb size. It has been reported that the roots of sunflower (10) and grapes (17) can produce substances which have cytokinin activity. If lily roots produce cytokinins they may increase the apex diameter and thus influence the number of leaves and floral buds. Recently, Carr et al. (5) and Jones and Phillips (9) have demonstrated that gibberellins are also produced in roots of some plants. Perhaps, it is an interaction between the gibberellins and cytokinins which produce the increased number of floral buds. The point being that a lily bulb which has an actively grow-

ing root system is in a different physiological state than a bulb which does not. Certainly, this must play a major role in the differences which have been observed between CTF, natural cooled, and precooled bulbs.

The data (Table 3, Fig. 3) confirms earlier reports by Hastings (8) and Smith (18) that an increase in bulb size will result in an increase in the number of floral buds, regardless of cultivar. We have found that the 'Ace' will produce more floral buds than 'Nellie White'. Thus, the genetic makeup of a specific cultivar plays an important role. The method of forcing merely alters the response observed.

The CTF method produced an increased number of leaves when compared with bulbs which have been precooled. This was true with both 'Ace' and 'Nellie White' and for both bulb sizes tested. Stuart and Doucette (23) and Blaney et al. (1) have reported that a preheating treatment will also produce an increased leaf number. Thus, it appears that at temperatures between 60° and 70° leaves are differentiated at the same time that the number of floral buds is being conserved. Perhaps, these factors are related.

Although no data have been presented to show the influence of the CTF method on leaf length, it was observed that the lower leaves of CTF bulbs (Fig. 5) were distinctly longer than those which were precooled in peat. This same response has been reported for naturally cooled lilies (3, 4, 7, 16). This aspect needs to be investigated in future experiments. From a commercial standpoint, this is a highly desirable effect.

The influence of the CTF method on days to flower produced variable results. In Experiment 1 (Table 3) no significant differences between precooled and CTF treated bulbs were evident, however, in Experiment 2 the CTF bulbs took longer to force (Fig. 1 and 2). These bulbs were, however, given only 5 weeks of cold instead of the 8 weeks which the precooled bulbs received. Perhaps, the difference in the length of the low temperature treatments produced the response. This response has been reported by Smith (18) who found that 'Croft' lilies took 4 days longer to force when given 5 weeks of 40° as opposed to 8 weeks of 40°. On the other hand, a position effect in the greenhouse may have produced the difference. Thus, for those individuals who are interested in programing of lilies, it appears that a specific temperature sequence will have to be utilized to produce the desired effect.

The data (Table 3, Fig. 4) show that the effect of the low temperature treatments on plant height is variable. It is concluded that the CTF method does not produce any undesirable effects. More important is the fact that the 'Ace' lily is taller than 'Nellie White' (Fig. 4). It appears that height of the plant is influenced more by the cultivar, the bulb size, and changes in greenhouse management.

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