Cooperative Extension Service
Michigan State University
Extension Bulletin E-1406 (Revised), November 1987

Producing Easter Lilies

By John Erwin, Royal Heins, Meriam Karlsson, William Carlson, and John Biernbaum

I. Introduction

A. Easter lilies are the third largest flowering pot plant crop grown in the United States with 10 to 11 million plants produced annually. Lily forcing information has changed dramatically during the last few years. This outline is offered as a guide and reference to forcing lilies with emphasis on new forcing information.

B. The date of Easter varies each year. Easter is the first Sunday following the first full moon, which falls on or after the vernal equinox. Dates of Easter vary from March 22 to April 25.

II. History

A. The Easter lily, *Lilium longiflorum,* is native to the Ryukyu Islands of southern Japan, and the islands Okinawa, Amami, and Erabu.

B. The latitude of Erabu Island is 30°N, which corresponds with the latitude of New Orleans. The photoperiod of Erabu varies from 14 hr. 13 min. to 10 hr. 14 min. The mean temperature of Erabu is 70°F.

C. *Lilium longiflorum* was introduced to England in 1819. Commercial production of bulbs was initially started in Bermuda in 1853. The Bermuda lily industry was ruined in 1898 by virus and nematode infestation.

D. Lily bulb production was centered in both Japan and the southern United States after 1898. World War II eliminated the dependence of the U.S. industry on Japanese-produced bulbs and a new center for bulb production was established in the northwestern U.S.

E. Today, Easter lilies are forced in the United States as seasonal pot plants, whereas most lilies grown in Western Europe and Japan are sold as cut flowers over an extended season.

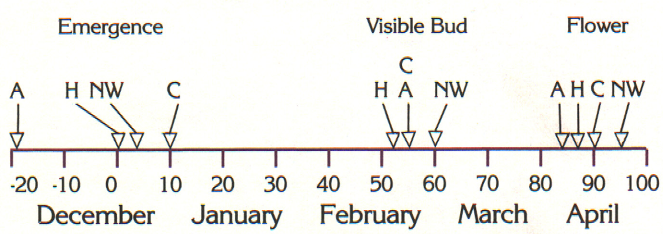
III. Cultivars

A. The two most important lily cultivars grown in the United States are 'Ace' and 'Nellie White.' The importance of 'Nellie White' continues to grow as 'Ace' becomes less important.

Compared to 'Ace,' 'Nellie White'
- is shorter
- has fewer leaves
- has wider leaves
- has more leaves at the base of the plant
- produces ½ to 1 less flower per plant grown from the same size bulb
- suffers less tip burn problems

B. A breeding program at Oregon State University selected shorter growing cultivars. Recent introductions include 'Chetco' and 'Harbor.' 'Chetco' is much shorter at flower than either 'Nellie White' or 'Ace.' Figure 1 shows a time line comparing the 6-year average date of emergence, visible bud and flower for 'Ace,' 'Chetco,' 'Harbor,' and 'Nellie White' for plants grown at Michigan State University.

A—Ace, C—Chetco, H—Harbor, NW—Nellie White



C. Cultivars from the Netherlands are likely to enter the American market. We have evaluated 2 cultivars grown from 5-inch bulbs. Compared to 'Nellie White' plants grown from 8- to 9-inch bulbs, these cultivars have:
- darker green foliage
- narrower leaves
- smaller flower size
- fewer flowers

IV. Bulbs

A. 'Ace' and 'Nellie White' bulbs are sold in the following bulb sizes:

Ace	Nellie White	Bulbs per Case
circumference in inches		
6½-7	Typically Not Sold	300
7-8	7-8	250
8-9	8-9	200
9-10	9-10	150
10-up	10-up	100

B. In general, the larger the bulb size, the greater the flower number.

C. The Easter lily bulb will either produce one shoot (single-nosed bulb) or two shoots (double-nosed bulb). The percentage of double-nosed bulbs is normally less than 5 percent. In the past, the two bulb types were sold separately. Now most are sold together, although limited quantities of double-nosed bulbs are available.

D. "Virus-indexed" plants grown from leaf cuttings are being experimentally produced. They may reduce or eliminate the need for bulbs at some time in the future.

V. Medium and Planting

A. The planting medium must be well-drained and well-aerated. Many components are acceptable for a lily medium. Most forcers today use a soilless medium. Never use perlite since it contains fluoride, which can cause leaf scorch.

B. Maintain medium pH between 6.0 and 7.0 and soluble salts between 0.5 and 0.8 (1:2). If flourides are present maintain higher pH (6.5 to 7.0) in the root media or water to tie up as much of the fluoride as possible.

C. Do not add superphosphate to the medium because it contains fluoride. Supply phosphorus through a regular liquid nutrition program, i.e., phosphoric acid.

D. Plant bulbs 1 inch from the bottom of a 6-inch standard pot so that a large section of the stem is below the medium surface. This increases the length of stem available for stem root development, which increases the vigor of the plant.

E. Drench all pots with a fungicide immediately after planting the bulbs to control *Pythium* and *Rhizoctonia*.

VI. Water

A. Do not allow plants to dry out since the lower leaves may yellow and flower bud abortion may occur.

B. Excess water may result in root rot. Therefore, take care when determining the watering frequency and the type of media in which the plants will be grown.

C. Water high in fluoride may cause leaf scorch.

VII. Nutrition

A. Proper nutrition is essential to produce a high quality Easter lily. Regular fertilizer applications will not increase plant height, but excessive salt levels within the media will decrease plant height.

B. High phosphorus levels were traditionally associated with leaf scorch in 'Croft' and 'Ace.' The problem is not a phosphorus toxicity, but a fluoride toxicity (from superphosphate, perlite, or fluorinated water).

C. A nutritional program of 200 ppm of N and K is acceptable for lily production. Which fertilizers to use depends on the desired pH response. In areas with high pH water, use acid residue fertilizers (e.g., ammonium nitrate and urea). Under low pH conditions, use alkaline residue fertilizers (e.g., calcium nitrate and potassium nitrate).

VIII. Flower Induction—Basic Concepts

A. Flower induction in the lily can be achieved with cold temperatures or long photoperiods.

B. In its native environment, *Lilium longiflorum* is probably induced to flower by long days (LD); plants typically flower in August.

C. Flower induction of Easter lilies in the United States is accomplished through 6 weeks of vernalization (cold and moist) treatment followed by LD treatment.

D. The length of the cooling (vernalization) treatment is critical. As the time period of the cooling treatment is extended:
- shoot emergence occurs earlier
- shoot emergence becomes more uniform
- the days from shoot emergence until flower decrease
- there is greater uniformity among plants in the time from shoot emergence until flower
- leaf number decreases
- leaf length decreases at the base of the plant
- internode length increases
- flower number decreases

E. Typically, bulbs are cooled for 6 weeks. Plant height at flower decreases as cooling increases from 0 to 6 weeks. Cooling longer than 6 weeks results in an increase in plant height at flower. Bulbs cooled longer than 6 weeks are often referred to as "overcooled." Overcooled bulbs have a low leaf number, long internodes, short lower leaves, and often look like an ice cream cone or an upside down Christmas tree. Plants cooled less than 6 weeks are referred to as "undercooled." Undercooled plants have a high leaf number, long lower leaves, short internodes, and a high flower number. Undercooled lilies may not flower by Easter.

F. Long days (LD) and cooling both affect induction. One week of cooling affects flower induction the same way in which one week of long days does. Long days are not used commercially to induce flowering due to uneven emergence of uncooled lily shoots and the large greenhouse space requirement. Long day treatment does not result in shorter basal leaves as is seen with cooled bulbs.

G. Plants are normally exposed to 1 to 3 weeks of LD upon emergence from the medium (following the cooling treatment). This is done to ensure that the plants are properly induced to flower. This procedure is often referred to as the "Insurance Policy." Long days are given by applying night interruption lighting of 10 footcandles or more with incandescent lights from 10:00 p.m. to 2:00 a.m.

H. Optimal temperatures for cooling 'Ace' and 'Nellie White' bulbs are 35° to 40°F and 40° to 45°F, respectively. If bulbs of both cultivars are cooled in the same cold storage, 40°F is the recommended cooling temperature.

IX. Flower Induction—Programming

A. The Pre-cooling Phase

1. Pre-cooling rooting is done on bulbs cooled in a pot as opposed to the shipping case.
2. The purpose of the pre-cooling phase is to develop a root system on the bulb prior to cooling, which leads to higher flower bud count.
3. Optimal root development occurs when the soil is moist and the soil temperature is maintained between 63° and 65°F.
4. The pre-cooling phase lasts from 1 to 3 weeks. The length of this phase is influenced by the arrival date of the bulbs and the date of Easter.
5. Take care not to allow excessive shoot elongation during this phase. Shoot emergence prior to cooling or during cooling often results in undesirable plant characteristics, such as excessive stem elongation and/or leaf drop following vernalization. If shoot emergence should occur during pre-cooling, expose the plants to a minimum of 2 footcandles of light from fluorescent bulbs continuously during cooling.

B. The Flower Induction Phase (Cooling)

1. Three methods are used to cool lilies commercially. They are natural cooling, controlled temperature forcing (CTF), and case-cooling.
   a. Natural cooling
      1) Uncooled bulbs are potted in late October and then rooted and vernalized using natural temperatures. Unheated greenhouses or coldframes are normally used to vernalize the bulbs. The media must be moist and soil temperatures must be maintained between 33° and 48°F for vernalization to occur. Media temperatures are checked twice a day and recorded so the hours of cooling can be calculated over time. Hours above 48°F are normally not counted as cooling temperatures. Bulbs should be cooled for 1,000 hours.
      2) Advantages of natural cooling are:
         - high leaf and flower number
         - long basal leaves
         - shorter plants
         - cooler is not needed
      3) The disadvantage of natural cooling is the dependence on prevailing weather conditions for cool temperatures. It can be difficult to maintain optimal cooling temperatures for 1,000 hours during some years.
   b. Controlled temperature forcing (CTF)
      1) Uncooled bulbs are potted in mid- to late October in a moist medium, rooted at 63° to 65°F for 2 to 3 weeks and are then vernalized in a cooler at 35° to 40°F for 'Ace' and 40° to 45°F for 'Nellie White.' The plants are moved to the greenhouse after 6 weeks. If shoots emerge while the plants are in the cooler, the vernalization temperature should be decreased to 34°F and/or the plants should be lighted continuously with a minimum of 2 footcandles supplied by fluorescent lamps.
      2) Advantages of CTF are:
         - high flower number
         - long basal leaves
         - precise temperature control
         - more uniform flowering
      3) The disadvantage of CTF is the requirement of cold storage space.
   c. Case-cooling
      1) Bulbs are cooled in the shipping case in moist peat moss either by the distributor prior to shipment or by the forcer. The forcer typically receives and pots the "pre-cooled" bulbs in the first half of December. Temperatures after potting are maintained between 63° and 65°F for approximately two weeks to encourage optimal root development.
      2) Advantages of case cooling are:
         - takes small amount of cooler space
         - the forcer does not need a cooler
      3) Disadvantages of case cooling are:
         - bulbs are often overcooled, especially if commercially case-cooled
         - overcooling results in lower flower and leaf number
         - short basal leaves result in upside-down Christmas tree appearance

X. Greenhouse Forcing

A. The Phase from Emergence of the Shoot Until Flower Initiation

1. Plants should receive a long day treatment for 1 to 3 weeks to ensure flower induction upon shoot emergence from the soil. One week is normally used on early emerging plants. Three weeks are normally used for late emerging plants, especially when Easter is early. This may require some sorting of plants, but will improve crop uniformity.

2. During the stage from flower induction (vernalization) to flower initiation, temperatures are controlled based on soil temperatures. Media temperatures of 60° to 62°F are typically used on years with late Easters as opposed to temperatures of 63° to 65°F on years with early Easters. Temperatures lower than 60°F result in reduced root development and potentially reduced flower number.
3. It is important to establish a good root system to minimize flower bud abortion and/or lower leaf drop.
4. Flower initiation typically occurs during the last 2 weeks of January and is normally complete when the plants are approximately 4 to 6 inches tall.
5. To determine if flower initiation has occurred, look at the shoot apex under magnification. If the apex has distinct bumps on it, flower initiation has occurred. Flower initiation has not occurred if the apex is round.
6. Applying growth retardants during the transitional stage from vegetative growth to flowering may reduce flower number.

B. The Phase from Flower Initiation to Visible Bud
   1. Rate of development.
      a. During this phase the grower has the greatest flexibility in determining the flowering date and the plant appearance at flower. Temperature has the greatest influence on the rate of Easter lily growth during this phase.
      b. Use the leaf counting technique to ensure proper timing of a lily crop. Once a lily shoot initiates a flower bud, no more leaves will form. At visible bud, all the leaves have unfolded. Therefore, if you know how many leaves have yet to unfold on a plant before the visible bud stage, you can calculate how many leaves must unfold each day (or week) in order to reach the visible bud stage by a particular date. By knowing the number of leaves that must unfold each week and by making a count of leaves that actually unfolded the previous week, you can determine if a crop is slow, fast or on time. Subsequently, the air temperature may be increased or decreased to hasten or delay plant development for proper crop timing. The following describes how to leaf count a lily crop.
         1. Start leaf counting 3 to 4 weeks after emergence or when plants are 4 to 6 inches tall. Examine the first plants to determine if flower initiation has occurred. If the first plants are still vegetative, examine a new set of plants 4 to 5 days later.
         2. Select a minimum of 3 to 5 plants for every bulb source and bulb size to estimate the average leaf number of the crop. Count how many leaves have unfolded and how many leaves have yet to unfold on each plant. Unfolded leaves are defined as those that are at an angle equal to, or greater than, 45° with the plant stem. Leaves yet to unfold are those that have an angle of less than 45° with the plant stem. A large needle and a magnifying glass will help you remove small, scale-like leaves near the shoot apex. The embryo-like flower buds will be present on reproductive plants. You can estimate the future bud count on these plants.
         3. Divide the number of leaves already unfolded by the number of days from emergence until the present date. This will tell how many leaves have unfolded each day to date.
         4. Determine the visible bud date. The visible bud date is normally 30 to 35 days prior to the expected market date (often Palm Sunday). It takes 30 days from visible bud to flower at 70°F and 35 days at 65°F.
         5. Divide the number of leaves that have yet to unfold by the number of days from the day of leaf counting until the expected visible bud date. This figure tells you how many leaves must unfold each day to achieve visible bud at the desired time.
         6. If the number of leaves to unfold each day is greater than the number of leaves unfolded each day from emergence until the day of counting, then increase the average greenhouse air temperature. In contrast, if the number of leaves to unfold each day is less than the number of leaves unfolded each day prior to leaf counting, decrease the average air temperature to slow development.
         7. In the greenhouse, mark the last unfolded leaves on several representative plants of each lot and bulb size. Mark each unfolded leaf either with a magic marker or hole punch, or place a wire hoop above all expanded leaves on the shoot but below the unexpanded leaves. We recommend using a wire hoop because plant appearance is not affected.
         8. Determine the leaf unfolding rate every 5 to 7 days. Compare the data to determine if the leaf unfolding rate was higher or lower than that necessary for proper timing. Adjust greenhouse temperatures accordingly.
         9. Another method of leaf counting is to plot the total number of leaves unfolded each time the leaves are counted. Compare the actual number of unfolded leaves to the number required on that date. The advantage of this system is that cumulative development is compared to desired development.
      c. The rate of leaf unfolding is a linear function of average daily temperature (Figure 1). In other words, the increase in the rate of leaf unfolding resulting from a 5°F increase in temperature from 55° to 60°F is the same as that from 70° to 75°F.

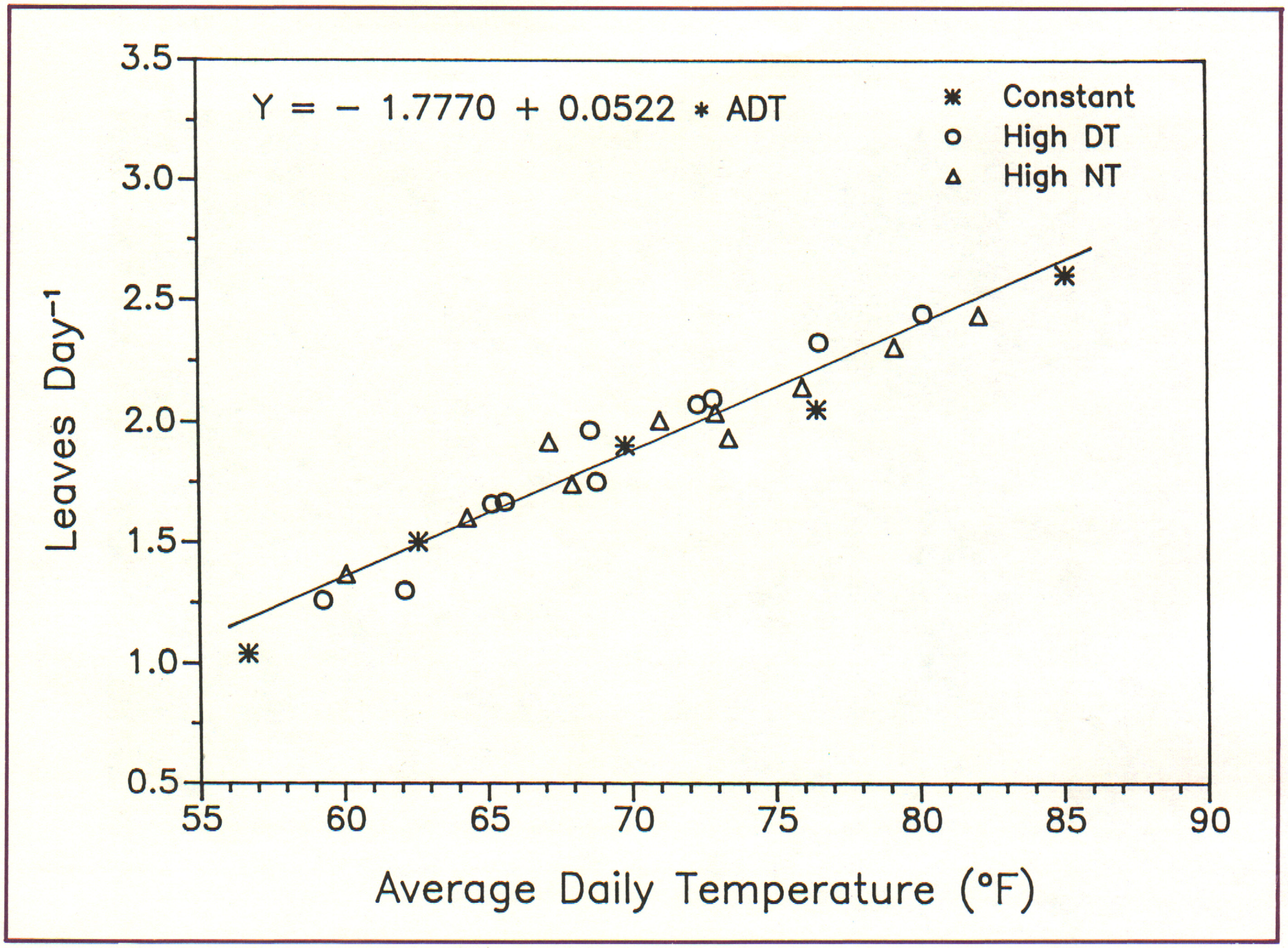


Figure 1. The effect of average daily temperature (ADT) on the number of Easter lily leaves unfolded per day with constant temperature regimens (*), high day temperature (DT) regimens (○), and high night temperature (NT) regimens (△). "Y" is equal to the predicted number of leaves unfolded per day.

2. Plant Morphology
   a. Day and night temperatures during the flower initiation to visible bud stage greatly influence final plant morphology (how the plant looks).
   b. Leaf length increases as night temperature decreases from 85° to 55°F. In one experiment, as night temperature decreased from 85° to 55°F, leaf length increased from 12 to 18 cm (4.7 to 7.1 inches).
   c. Similarly, flower length increases as night temperature decreases from 85° to 55°F.
   d. Plant height increases as day temperature increases (Figure 2). In contrast, plant height decreases as the night temperature increases (Figure 3).
   e. The difference between day and night temperatures (day temperature-night temperature) determines final plant height. Plants progressively become taller as the difference increases from a negative value (cool day and warm night) to a positive value (warm day and cool night). Plants with an equal difference between day and night temperatures will have similar plant height at flower irrespective of the absolute day and night temperatures, grown between 55° and 85°F (Figure 4).
   f. Leaf orientation, defined as the position of the leaf tip relative to the leaf base, also increases as the difference between day and night temperatures increases.
   g. The elongation response of lily stems to day and night temperatures is rapid. Therefore, temperatures can be altered to stimulate or retard elongation on a daily basis. Figure 5 plots leaf unfolding rate versus day and night temperatures. Many combinations of day and night temperatures can be used to achieve a particular leaf unfolding rate; each combination will result in a different plant height. To use Figure 5, determine your required leaf unfolding rate by leaf counting. Find the line that represents this leaf unfolding rate, then pick a day/night temperature combination that will give you your desired leaf unfolding rate. For example, suppose you needed 1.6 leaves to unfold per day. Figure 5 shows two possible temperature combinations you may select to obtain this number of leaves. The day/night

Figure 2. The influence of day and night temperature on *Lilium longiflorum* morphology at 14°C (57°F) night temperature.

Figure 3. The influence of day and night temperature on *Lilium longiflorum* morphology at 30°C (86°F) day temperature.

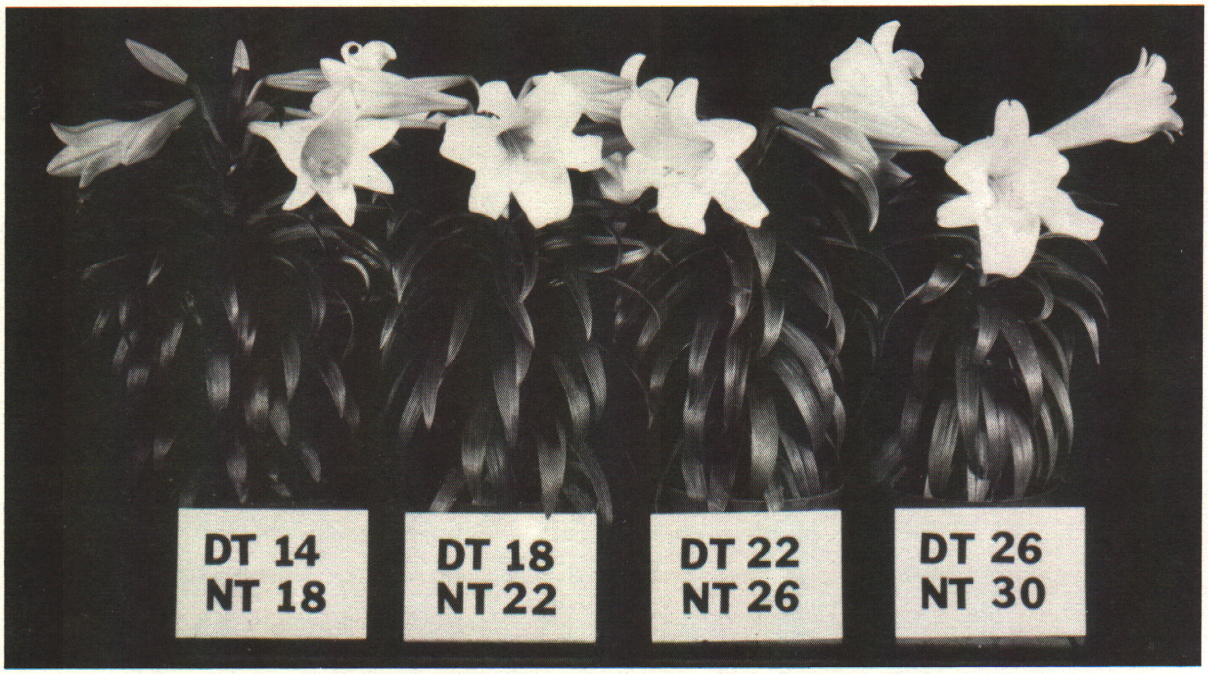


Figure 4. The difference between day and night temperature on *Lilium longiflorum* morphology at flower. Notice that as long as the relationship between day and night temperatures is equal, the plants appear similar at flower.

temperature combination of 70°F and 61°F will result in a much taller plant than the combination of 57°F and 70°F. While plant height will differ, leaf unfolding and rate of development will remain the same.

h. There are several ways to select the right day/night temperature combination. One method is graphical tracking. When using graphical tracking, actual plant height is plotted against desired plant height. Desired height during each stage of forcing can be determined by drawing lines between plant height at emergence and visible bud and between visible bud and flower. Years of experience have shown that a lily crop doubles in height from visible bud to flower under commercial conditions. Figure 6 is a sample of graphical tracking. To have a 22- to 24-inch lily including the pot at flower, the plant itself must be 16 to 18 inches at flower. Since the plant doubles in height from visible bud to flower, it should be 8 to 9 inches tall at visible bud (14 to 15 inches including the pot). Plant height at emergence is 0 inches. The lines provide a window of plant height the crop should stay between during forcing. An example of maintaining the lily crop in or near the window of desired plant height is also shown. The graph in figure 6 provides a range of plant heights. Try to maintain actual plant heights in this range during forcing.

i. Leaf chlorosis occurs whenever night temperature is greater than day temperature. The degree of chlorosis increases as the night temperature increases relative to the day temperature. The leaf chlorosis is not permanent. Plants will either grow out of the chlorosis by flower, or the chlorosis can be reversed by decreasing the night temperature below the day temperature.

j. Light intensity does not influence the rate of Easter lily development. However, it does influence plant morphology. As light intensity increases, final plant height decreases. In addition, as light intensity decreases to very low levels, more flower bud abortion occurs.

k. Light quality influences lily plant morphology. As the amount of far-red light increases relative to red light, plant height increases, the leaf becomes lighter green, and leaves become thinner. Therefore, do not expose lilies to incandescent light (high far-red source) after flower initiation.

l. Photoperiod influences plant height. Plants are shorter when grown under short days compared to long days.

C. The Phase from Visible Bud to Flower

1. The time from visible bud (VB) to flower ranges from 24 days with an 85°F day and night temperature to 42 days with a 57°F day and night temperature. The relationship between day and night temperatures and the rate of development from the visible bud stage until flower is not linear. Instead, the relative increase in the growth rate decreases as temperature increases. Therefore,

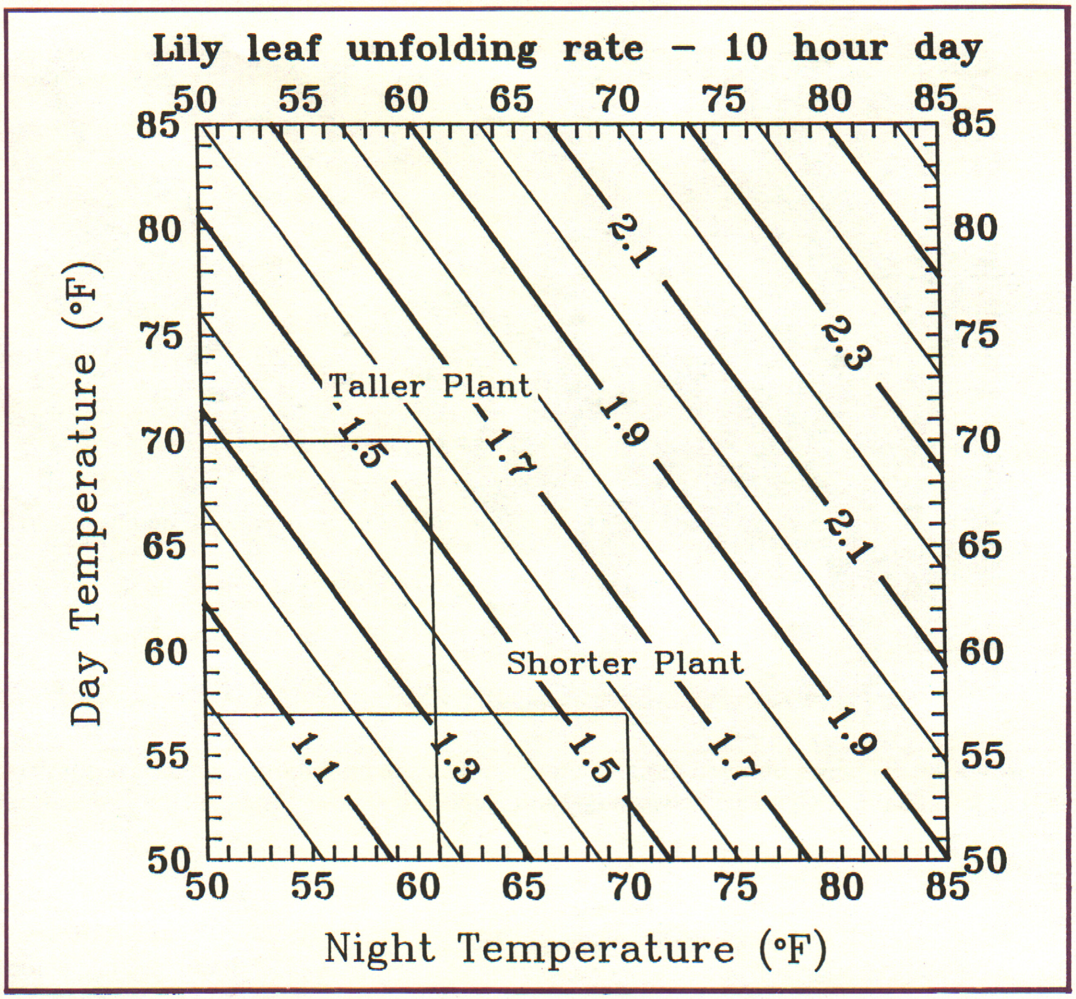


Figure 5. Lily leaf unfolding rate—10 hour day.

increasing the temperature from 55° to 60°F is more effective in reducing the time from VB to flower than increasing the temperature from 75° to 80°F.

2. Very little benefit is realized from raising temperatures above 75°F. The reduction in predicted days to flower with increasing temperature is shown below.

Temperature (°F)	Days from VB to Flower	Decrease in Days from VB to Flower Due to a 5°F Increase in Temperature
55	42	
60	38	4
65	34	4
70	31	3
75	27	4
80	25	2
85	24	1

3. Many forcers assume plant height will double from VB to flower. The increase in plant height from the visible bud stage to flower is influenced by the difference between day and night temperatures. Therefore, forcers have some control of the increase in plant height after visible bud. In one experiment at MSU, as the difference between day and night temperatures increased from -30°F to 30°F, the increase in plant height from VB to flower increased from 5 inches to 11 inches.

XI. Gases

A. Do not use carbon dioxide on lilies because an increase in CO_2 concentration has been associated with an increase in plant height without any additional benefits, such as increased flower bud count.

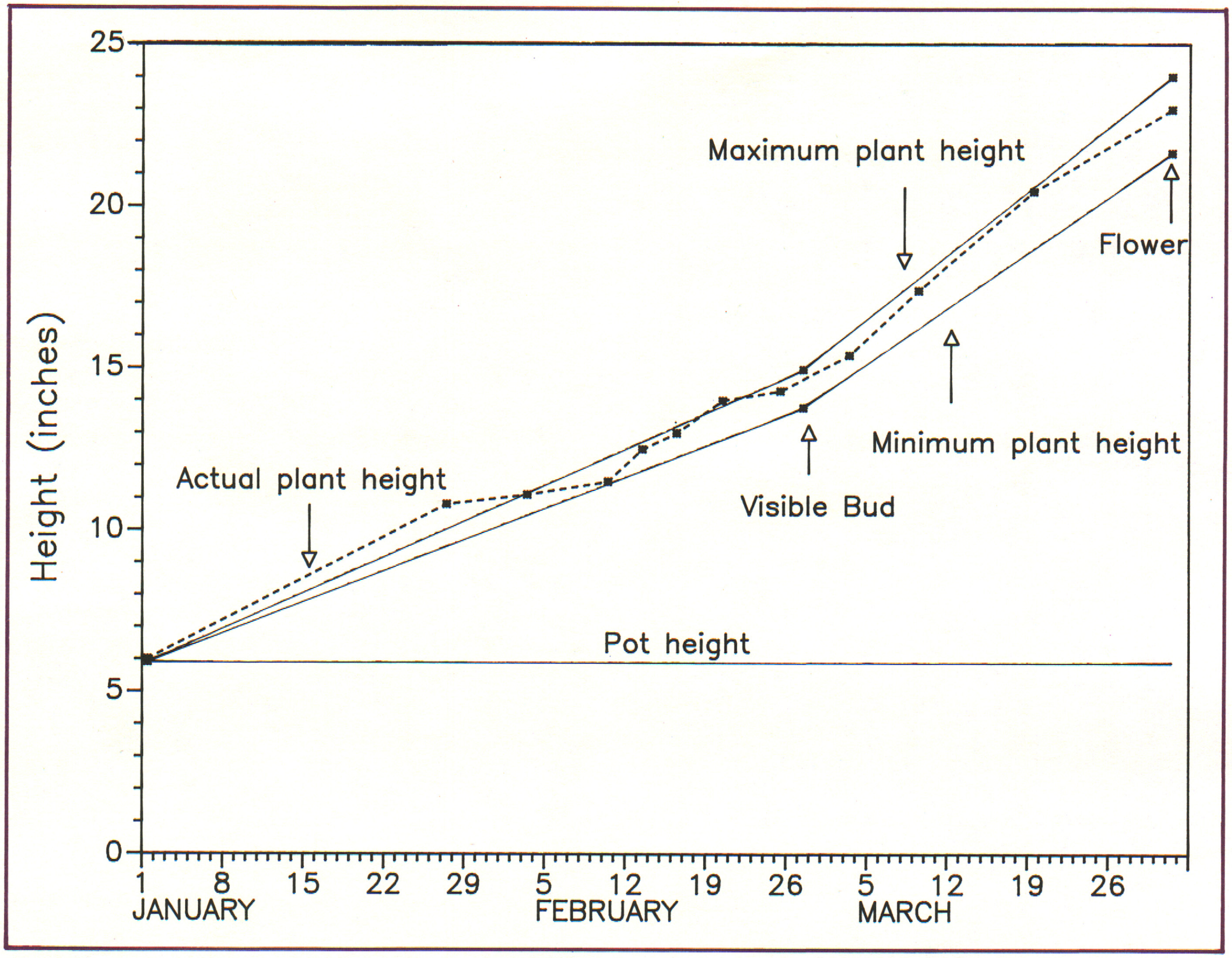


Figure 6. Graphical tracking of lily plant development.

XII. Growth Regulators

A. Lilies respond to an Ancymidol *(A-Rest)* spray or drench.

B. Do not apply growth regulators during flower initiation (normally mid- to late January) since a reduction in flower number may occur.

C. In general, drenches of *A-Rest* are twice as effective as sprays in reducing shoot length per mg active ingredient.

D. Ancymidol effectiveness is greatly decreased when applications are made as drenches in a bark medium or when the medium pH is low. Effectiveness is also reduced when the day temperature is cooler than the night temperature.

E. Calculations

1. 1 quart of *A-Rest* contains 250 mg active ingredient (a.i.)
2. Typical soil drench is 0.25 mg of *A-Rest* in 6 oz of water per 6-inch pot
3. 1 quart of *A-Rest* will drench 1,000 plants with 0.25 mg
4. Typical spray application is 0.50 mg *A-Rest* in 10 ml (1/3 oz) of water (500 plants per quart)

XIII. Diseases

A. Botrytis *(Botrytis elliptica)* is a fungal disease identified as a grey mold growing on the surface of leaves and/or flowers. Well-ventilated greenhouses and sanitary conditions will normally prevent this disease. A number of fungicides will control Botrytis. If plants are to be stored in a cooler prior to marketing, use preventive measures, such as fungicide applications and low humidity, to stop infestation of flower buds.

B. Root Rot is a difficult disease to control. In general, any discoloration of the roots from a white color suggests a potential root rot problem. Assume that the potential for root rot always exists. Therefore, use preventive fungicide soil drenches. Start soil drenches immediately after potting the bulbs. Include fungicides for both *Pythium* and *Rhizoctonia.* Apply fungicides as a bulb dip prior to potting, as a drench immediately prior to placement in the cooler, immediately upon placement of the plants in the greenhouse, and every 3 to 4 weeks thereafter.

C. There are a number of viruses that infect Easter lilies, e.g., fleck, cucumber mosaic, etc. Normally, these are beyond control. The best advice is to purchase bulbs from a reliable source.

D. Twist is a disease that is not well understood. If present, it will appear when plants have unfolded 40 to 50 leaves. A half-dozen or so leaves will twist into a semi-circle. There is no known control but plants normally grow out of this disease and are often still marketable.

E. See Extension bulletin E-2017, *Chemical Disease Control for the Michigan Greenhouse Industry,* for recommended control measures.

XIV. Insects

A. The major greenhouse insect pest on lilies is the aphid. In large numbers, the aphid can cause leaf and flower distortion. They are often most damaging at the visible bud stage. Systemic insecticides prior to visible bud are especially effective.

B. The bulb mite, *Rhizoglyphus echinopus,* can severely damage the lily bulb during development. Dip a bulb in a miticide prior to planting to control this pest. Soak bulbs for 5 to 15 minutes. Use a systemic insecticide to control the bulb mite after potting and emergence.

C. Fungus gnats are occasionally a problem when the growing medium stays wet for extended periods of time. Larvae of the fungus gnat can cause severe root damage when present in large numbers. Use an insecticide drench to control this pest.

D. See Extension bulletin E-2014, *Insect and Mite Management in Commercial Greenhouses,* for recommended control measures.

XV. Physiological Problems

A. Leaf scorch is a disorder characterized by die-back of the leaf tips. Sometimes it is confused with *Botrytis* infections, but fluoride toxicity is usually the cause. Avoid superphosphate, perlite, and fluorinated water. 'Ace' is more susceptible to tip burn than 'Nellie White.'

B. Yellowing of lower leaves can be due to the development of root rot, poor aeration of the planting medium, low light due to tight spacing or improper fertilizer levels. Check all possibilities.

C. Many factors can be involved in floral bud abortion. Among these are ethylene, root rot, low light intensity, water stress, and high temperatures.

Issued in furtherance of Cooperative Extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. W.J. Moline, Director, Cooperative Extension Service, Michigan State University, E. Lansing, MI 48824.

Flowers

11/87-New-10M-SDC/HP-Price: 50¢