Crop: Easter Lily
Scientific Name: *Lilium longiflorum*

I. Introduction

A. Easter lilies are the third most important major flowering pot plant crop grown in the United States with 10 to 11 million plants being produced annually. Lily forcing information has changed dramatically during the last few years. This outline is offered as a guide and reference for lily forcing 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 varies of Erabu from 14 hr. 13 min. to 10 hr. 14 min. The mean temperature of Erabu is 21°C (70°).

C. *Lilium longiflorum* was introduced to England in 1819. Commercial production of bulbs 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 pacific northwest of the 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'. Compared to 'Ace', 'Nellie White':

1. is shorter
2. has fewer leaves
3. has wider leaves
4. has more leaves at the base of the plant
5. produces 1/2 to 1 less flowers per plant grown from the same size bulb
6. suffers less tip burn problems

IV. Bulbs

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

Ace	Nellie White	Bulbs per Case
6 1/2 - 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%. In the past, the two bulb types were sold separately, now most are sold together although limited quantities of double-nosed bulbs are available.

V. Medium and Planting

A. Transplanting medium should be well-drained and well-aerated. Many components are acceptable for a lily medium. Most forcers today use a soilless medium. Perlite should never be used as it contains fluoride which can cause leaf scorch.

B. The pH of the medium should be maintained between 6.0 and 7.0 and the soluble salts should be maintained between 0.5 and 0.8 (1 part soil :2 parts water). The pH should be maintained higher (6.5 to 7.0) if fluorides are present in the root media or water to tie up as much of the fluoride as possible.

C. Superphosphate should not be added to the medium because it contains fluoride. Phosphorous should be supplied through a regular liquid nutritional program, i.e. phosphoric acid.

D. Bulbs should be planted 0.5 to 1-inch from the bottom of a 6" standard pot so that a large section of the stem is below the media surface. This increases the length of stem available for stem root development which increases the vigor of the plant.

E. Some growers plant bulbs on the pot bottom to speed planting. Care should be exercised when bulbs are placed on the pot bottom to avoid overwatering and will decrease root growth.

F. Bulbs should be dipped in a fungicide and miticide prior to potting or pots should be drenched with a fungicide and miticide immediately after planting the bulbs to control *Pythium*, *Rhizoctonia* and bulb mites.

VI. Water

A. Plants should not be allowed to severely dry out as flower bud abortion may occur.

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

C. Water high in fluoride (1 ppm) may cause leaf scorch, especially on 'Ace'.

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). Phosphorous should be included in the nutritional program as it has been shown to reduce lower leaf yellowing when A-rest is applied.

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

VIII. Flower Induction - Basic Concepts

A. Flower induction in the lily can be achieved with cold temperatures or with long photoperiods when they follow a period of cold.

B. Flower induction of Easter lilies in the United States is accomplished through a 6-week vernalization (cold and moist) treatment.

C. The length of the cooling (vernalization) treatment is critical. As the time period of the cooling treatment is extended:

1. shoot emergence occurs earlier after cooling
2. shoot emergence becomes more uniform after cooling
3. the days from shoot emergence until flower decrease
4. there is greater uniformity among plants in the time from shoot emergence until flower
5. leaf number decreases
6. leaf length decreases at the base of the plant
7. internode length increases

8. flower number decreases

D. 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 and 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, have long lower leaves, short internodes, and a high flower number. Undercooled lilies may not flower by Easter.

E. Long days (LD) and cooling are additive in their effect on flower induction. One week of long days is equal to 1 week of cooling in its effect on flower induction. 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.

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

G. Optimal temperatures for cooling 'Ace' and 'Nellie White' bulbs are 38-40°F and 40-45°F, respectively. If bulbs of both cultivars are cooled in the same cold storage, 41°F is suggested as a cooling temperature.

IX. Flower Induction - Programming

A. The Rooting Phase

1. Bulbs are rooted in a pot, not the shipping case.

2. The purpose of the rooting phase is to develop a root system on the bulb prior to cooling, which leads to higher flower bud count, shorter lower internodes and longer lower leaves

3. Optimal root development occurs when the soil is moist and the soil temperature is maintained between 63°F and 65°F. The soil should

not be saturated.

4. The rooting phase lasts from 1-3 weeks. The length of this phase is influenced by the arrival date of the bulbs and the date cooling is started.

5. Care must be taken 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 rooting, the plants should be lighted continuously with a minimum of 2 footcandles of light from fluorescent bulbs cooling.

B. The Flower Induction Phase (Cooling)

1. Three methods are used to cool lilies commercially. They are:

   a. Natural cooling

      1) Natural cooling - uncooled bulbs are potted in late October and then rooted and vernalized using natural temperatures. Unheated greenhouses or cold frames are normally used to vernalize the bulbs. The media must be moist and soil temperatures must be maintained between 33°F 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 should not be counted as cooling temperatures. Bulbs should be cooled for 1000 hours.

      2) Advantages of natural cooling are:

         a) high leaf and flower number

         b) long basal leaves

         c) shorter plants

         d) a 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 1000 hours during some years.

b. Controlled temperature forcing (CTF)

1) Controlled temperature forcing (CTF) - uncooled bulbs are potted in mid-to-late October in a moist medium, rooted at 63-65°F for 2-3 weeks and are then vernalized in a cooler at 38-40°F for 'Ace' and 40-45°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 35-37°F and/or the plants should be lighted with a minimum of 2 footcandles of light supplied by fluorescent lamps.

2) Advantages of CTF are:

a) high flower number

b) long basal leaves

c) precise temperature control

d) more uniform flowering

3) The disadvantage of CTF is the requirement of cold storage space.

c. Case-cooling

1) Case-cooling - bulbs are cooled in the shipping case in moist peat moss either by the distributer prior to shipment to the forcer or by the forcer. The forcer typically receives and pots the 'pre-cooled' bulbs in late November or early December. Temperatures after potting are maintained between 63°F and 65°F for approximately two weeks to encourage optimal root development.

2) Advantages of case cooling are:

a) that it only takes small amount of cooler space per bulb

b) the forcer does not need a cooler

3) Disadvantages of case cooling are:

a) rapid short emergence can occur after potting before roots have a chance to develop. This results in short lower leaves

b) bulbs are sometimes overcooled

b) overcooling results in lower flower and leaf number

c) short basal leaves result in upside-down Christmas tree appearance

C. The Emergence of the Shoot Until Flower Initiation Phase

1. Plants should receive a long day treatment for 1 to 3 weeks to insure 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 until the short meristem is above the soil line. Media temperatures of 60-62°F are typically used on years with late Easters as opposed to temperatures of 63-65°F on years with early Easters. Temperatures lower than 60°F result in reduced root development and potentially reduced flower number. After the meristem is above the soil line, temperatures are controlled by air temperatures.

3. It is important to establish a good root system to minimize flower bud abortion and/or flower leaf drop.

4. Flower initiation typically occurs during the last 2 weeks of January and is normally complete when the plants are approximately 4-6 inches tall.

5. A crude determination of flower initiation can be made by observing or feeling a swelling at the top of the shoot. It is recommended that one look at the shoot apex under magnification to insure that flower initiation has occurred. Flower initiation has not occurred if the apex is round. If the apex has distinct bumps on it, flower initiation has occurred.

6. Growth retardant applications during the transitional stage from vegetative growth to flowering may reduce the flower number.

D. Flower Initiation Until the Visible Bud Phase

1. Rate of Development

a. This is the phase of lily forcing when the grower has the greatest flexibility in determining the flowering date and the plant appearance at flower. The environmental factor which has the greatest influence on the rate of Easter lily growth during this phase is temperature.

b. Leaf counting is a technique used to insure 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 one knows how many leaves have yet to unfold on a plant before the visible bud stage, one 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 which must unfold each week and by making a count of leaves which actually unfolded the previous week, one 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 description describes how to leaf count a lily crop.

1) Leaf counting is usually started 3 weeks after emergence or when plants are 3-5 inches tall. The first plants are examined to determine if flower initiation has occurred. If the first plants examined are still vegetative, a new set of plants is examined 4-5 days later.

2) A minimum of 3-5 plants for every bulb source and bulb size should be taken 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 normally defined as those leaves which are at an angle equal to or greater than 45° with the plant stem. Leaves yet to unfold are defined as those leaves which have a 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. An estimate of the future bud count can be made 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 30-35 days prior to the expected market date unless one wishes to flower plants especially early. Ash Wednesday is a good choice for visible bud. It takes 30 days from visible bud to flower at 70°F (21°C) and 35 days at 65°F (18°C).

5) Divide the number of leaves which have yet to unfold by the number of days from the day leaf counting starts 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 the average greenhouse air temperature should be increased. 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, the average air temperature should be decreased to slow development.

7) In the greenhouse, mark the last unfolded leaves on several representative plants of each lot and bulb size. Different methods can be used. They include marking each unfolded leaf with a marker or hole punch or by

placing a wire hoop above all expanded leaves on the shoot but below the yet unexpanded leaves. We recommend the use of a wire hoop because the appearance of the plant is not affected.

8) Count and record the average number of leaves unfolded daily twice a week. Compare the data and determine if the leaf number was higher or lower than that which was necessary for proper timing. Adjust greenhouse temperatures accordingly.

9) A modification of the traditional leaf counting technique is to plot the total number of leaves unfolded each time the leaves are counted. The actual number of unfolded leaves is compared to required number on that date. The advantage of this system is that the cumulative development is compared with the desired development.

c. The rate of leaf unfolding is a linear function of average daily temperature. 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. Leaf unfolding is faster on plants grown from large bulbs than small bulbs when plants are grown at the same temperature.

2. Plant Morphology

a. The day and night temperature during this 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 the day temperature increases. In contrast, plant height decreases as the night temperature increases.

e. The Difference between day and night temperature (DIF=day temperature-night temperature) is the relationship which determines final plant height. Plants progressively become taller as DIF increases from a negative value (cool day and warm night) to a positive value (warm day and cool night). Plants with an equal DIF will have similar plant height at flower irrespective of the absolute day and night temperatures, grown between 55 and 80°F.

f. Leaf orientation, defined as the position of the leaf tip relative to the leaf base, also increases as the difference between the day and night temperature increases.

g. The elongation response of lily stems to day and night temperature is rapid. Therefore, temperatures can be altered to stimulate or slow elongation on a daily basis. Many combinations of day temperature and night temperature can be chosen for a particular leaf unfolding rate; each combination will result in a different plant height. The day and night temperature combinations of 70°F and 60°F will give a much taller plant than the combination of 60°F and 70°F. While the plant height will differ, leaf unfolding and rate of development will be the same.

h. How do you know which day and night temperature combination to choose? One method to use is graphical tracking. When using graphical tracking, actual plant height is plotted against desired plant height. How do you know your desired height at all times during forcing? One simple way is to draw lines between plant 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 typical commercial conditions. So, if we want a 22-24"lily including the pot at flower, the plant itself must be 16-18" at flower. Since the plant doubles from visible bud to flower, it should be 8-9" tall at visible bud (14-15" including the pot). Plant height at emergence is 0" (6" above the bench). The lines provide a window of plant height the crop should stay between during forcing.

i. Leaf chlorosis occurs whenever the night temperature is greater than the 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, flower bud abortion increases.

k. Light quality influences 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, lilies should not be exposed to incandescent lighting after flower initiation unless one wishes to promote stem elongation. Photoperiod influences plant height; plants are shorter when grown under short days compared to long days.

3. The Visible Bud Until lower Phase

a. The length of time from visible bud (VB) to flower ranges from 24 days with an 85°F (30°C) day and night temperature to 42 days with a 57°F (14°C) day and night temperature. The relationship between day and night temperature and the rate of development from the visible bud stage until flower is not linear. Instead, the response in the rate of growth to increasing temperature decreases as temperature increases. Therefore, increasing the temperature from 55 to 60°C is more effective in reducing the time from VB to flower than increasing the temperature from 75 to 80°F.

b. The benefit from raising temperatures above 70°F decreases rapidly. The reduction in predicted days to flower with increased temperature is shown below.

Temperature	Days VB to Flower	Decreased in Days from VB to Flower Due to a 5°F Increase in Temperature
55	42	4
60	38	4
65	34	3
70	31	3
75	27	2
80	25	1
85	24	0

c. 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 the day and night temperature. Therefore, forcers have some control of the increase in plant height. In one experiment at MSU, as the difference between day and night temperature increased from -30°F to 30°F, the increases in plant height from VB until flower increased from 5 inches to ll inches.

X. Gases

A. It is not necessary to use carbon dioxide on lilies. No additional benefits such as increased flower bud count have been observed.

XI. Growth Regulators

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

B. Growth regulator applications should not be made 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 a drench 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. One quart of A-Rest contains 250 mg active ingredient (a.i.).

2. Typical soil drench is 0.25 mg of A-Rest in 6 ounces of water per 6" pot.

3. One quart of A-Rest will drench 1000 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).

XII. Diseases

A. *Botrytis* (*Botrytis elliptica*) is a fungal disease. Botrytis can be 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. When observed on leaves or foliage, it can be controlled by a number of fungicides. If plants are to be stored in a cooler prior to marketing, preventative measures such as fungicide applications and low humidity are important to stop infestation of flower buds.

B. In general, any discoloration of the roots from a white color suggests a potential root rot problem. It is best to assume that the potential for root rot always exists. Therefore, the use of preventative fungicide soil drenches is advised. Soil drenches should start immediately after potting the bulbs. Drenches should include fungicides for both *Pythium* and *Rhizoctonia*. Fungicide should be applied as a bulb dip prior to potting, and as a drench immediately prior to placement in the cooler, immediately upon placement of the plants in the greenhouse, and every 3-4 weeks thereafter.

C. There are a number of viruses which infest Easter lilies, i.e. fleck, cucumber mosaic, etc. Normally, the forcer cannot do anything to control them. The best advice is to purchase bulbs from a reliable source.

D. Twist is a disease which is not well understood. If present, it will appear when plants have unfolded 40-50 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 Michigan State University Bulletin E-2017 for recommended control measures or see 'Plant Problem Control' (PPC) on SON.

XIII. Insects

A. The major greenhouse insect pest 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. A bulb dip containing a miticide is recommended prior to planting the bulbs to control this pest. Bulbs should be soaked for 5 to 15 minutes. A systemic insecticide can 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. An insecticide drench is effective in controlling this pest.

D. See Michigan State University Bulletin E-2014 for recommended control measures or see 'Plant Problem Control' (PPC) on SON.

XIV. 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, 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. The most common cause is tight spacing.

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