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Response of flowering in lily to light and temperature: Advances

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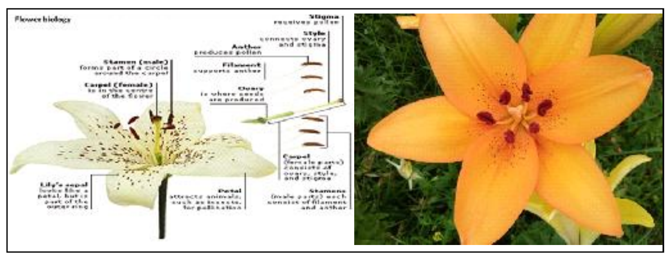
In geophytes, the process of flowering involves a series of molecular, biochemical and physiological mechanisms for development of reproductive organs. Sensing and integration of external factors like temperature, photoperiod, stress etc. by the plant at optimum time are necessary for floral development. These factors can be tapped to prepare to plant to induce flowering at a desired period of time. This operation has done wonders in terms of producing flowers during off-season, increases the farmer’s income, provide employment through the year, satisfy the consumer need at specific time etc.

Flower forcing refers to modification of the vegetative bud into flower bud in the plant or bulb by means of various interventions. Thus flower forcing can be done with number of external factors depending on the differential behavior of plant at flowering time. It can be done through use of chemicals like plant growth regulators, adjusting factors that affect flowering like photoperiod, temperature and humidity or by use of mechanical means like pruning, leaf trimming, ringing and breaking dormancy. In lily flower forcing is done by making alteration in temperature and photoperiod. Lilies are generally grouped into the Asiatic, Oriental and Longiflorum hybrids and all these hybrids have some similarities in certain characters. The Asiatic hybrids were developed by crossing different Asian species and have small saucer shaped flowers which are sky facing and are non- fragrant. Oriental hybrids are off-springs of *L. auratum* and *L. speciosum*. The position of flowers is horizontal having white and pink color and are highly fragrant. *Longiflorum* hybrids, also known as Easter lilies, have downward facing flowers which are fragrant and late blooming. The new groups of hybrids developed are “LA, OT, LO and OA hybrids”. LA hybrids are obtained by crossing *L. longiflorum* and Asiatic Lily. OT hybrids are crosses of Oriental and Trumpet Lily, LO hybrid of *L. longiflorum* and Oriental Lily and OA hybrids of Oriental and Asiatic Lily.

Flower biology : Lily flower has three sepals and three petals. The outer whorl comprises sepals which looks like petals, also called as tepals, Inner to this whorl there are three petals. The flower has six stamens which are placed around the carpel. The carpel comprises three fused tubes of style with one stigma.



Temperature : Lily produces good quality flowers, provided the root system is properly established. The optimum temperature for the root establishment during the first growing cycle is 12 to 13^0C. High temperatures during late stages of florogenesis can cause shorter stems, fewer flower buds per stem and increase the risk of disease infection. Lower temperatures can result in flower deformation (Kamenetsky, 2014) and extends the vegetative phase. Asiatic hybrids grow very well under a day temperature of 21 to 22^0 C and night temperature of 14 to 15^0C. However, the day temperature upto 25^0C and night temperature upto 8 to 10^0 C is also acceptable. In case of oriental hybrids, the optimum temperature during day and night is 20 to 22^0 C and 15 to 17^0 C, respectively. The bud drop and yellowing of foliage occur if temperature lowers down below 15^0 C. However, it can tolerate a temperature of upto 25^0 C. In *Longiflorum* hybrids the acceptable day and night temperature is upto 24^0 C and 14^0 C, respectively.

Light intensity : Lily grows well under moderate light intensity, so shade nets used to reduce the light intensity from 50 to 75 % as per the natural light intensity of the area. However, the poor light intensity causes abscission, bud drop and weak stem and very high light reduces the stem length and causes leaf scorching (APEDA, 2006). Zhang *et al*. (2015) observed that the chlorophyll a and b were highest at 80 % shade net and plant height, flower bud length and flower diameter were highest at 75% shade. Light quality also affects the plant's response to vernalization; for example, a low red:far red light ratio in *L. longiflorum* is antagonistic to vernalization in the context of flower initiation. Plants exposed to a high red:far red ratio were completely induced to flowering by a 4-week vernalization treatment, while vernalization for 8 weeks under light with a low red:far red ratio was not inductive for flowering (Erwin, 2006).

Overview of recent developments : In lilium flower initiation takes place during active growth following development of several leaves and florogenesis is enhanced by vernalization and long photoperiods (Kamenetsky *et al.*, 2012). The treatment of bulbs with low temperature and long photoperiods to initiate flowering is called as programming of bulbs. Thus environmental conditions during Lilium bulb production can have a great effect on subsequent forcing by affecting the maturity and level of dormancy of the bulbs at harvest, leaf number, and emergence rate. Flower differentiation respond positively to a wide range of temperature (13-27°C) in *L. longiflorum* (Miller, 1993) and a long photoperiod supports flower development. The vernalization period can be partly replaced by a long photoperiod given at the shoot emergence stage (Weiler and Langhans, 1972). In cold areas bulbs are planted in spring and shoot emerges and elongates when the temperature reaches 11-12°C. Flower initiation occurs simultaneously. Concurrent with flower formation and development, new inner scales are formed, and this process increases the bulb size. Following the scale formation, leaf primordia for the next season are initiated within the bulb. In comparison, during the annual development of *L. longiflorum* in warm-climate areas, sprouting and rosette development occur in autumn soon after planting in open fields, but the shoot does not elongate until spring. Leaf unfolding begins when the average temperatures increase to above 5°C. Under these conditions, floral induction is completed by late winter and flower initiation occurs in early spring. The annual developmental cycle in Asiatic, Oriental, and other hybrids is basically similar to that in *L. longiflorum* with differences in the timing of each developmental stage. The bulbs sprout in spring and flower in late spring to early summer (Asiatic) or summer (Oriental). In some earlier cultivars of Asiatic hybrids, flowering is initiated prior to bulb harvesting. However, in most of the newly released Asiatic and Oriental hybrids, flowering is initiated during active growth in spring. A cold period is necessary for flower initiation in all types of hybrids (Okubo and Sochacki, 2012).

In Asiatic lily the plant takes 30-35, Oriental lily 50-55 and Easter lily 30-40 days to flower from visible bud stage. For flower forcing the Asiatic lily is cooled at 2-5^0 C for 6-10 weeks, Oriental lily cooled at 2-4^0 C for 8-10 weeks and Easter lily cooled at 2-7^0 C for 6 weeks or 4.5-7.5^0 C for 3 weeks. The bulbs will not flower if they are exposed to temperature of 21^0 C or above after harvesting (Misra and Misra, 2013).

Leaf counting : Unlike many bulbs, Easter lily bulbs never undergo dormancy stage and bulbs will sprout if exposed to suitable environment. Forcing of Easter lily is not an easy task because the flowers are supposed to be made available between March 22 to April 25 as Easter is the first Sunday following the first moon after the vernal equinox. So depending on the moon cycle, Easter can fall between March 22 to April 25 and the crop is to be scheduled at this period of time. In order to determine the appropriate temperature manipulation, growers use a tedious method called leaf counting. Leaf counting is a technique which is helpful to determine the flower appearance date in Easter lily. After the floral initiation the number of leaves is fixed. The leaf counting starts 3-4 weeks after the emergence of shoot. Select three to five plants randomly. Determine first number of unfolded leaf and then yet to unfold leaves. The leaf tip angled at 45° from stem is considered as unfolded leave, punch this leaf and count all unfolded leaves on plant. Now count all the remaining leaves on shoot apex which are yet to unfold with the help of needle, microscope and hand-lens. Also note down the date of sampling. Add the number of leaves unfolded and yet to unfold. Count the number of days between sampling date and desired bud visible date (VB). For example the sampling date is January 20 and desired visible bud is March 1st so there are 40 days to unfold all leaves. Now let the number of unfolded leaves is 34 and yet to unfold is 58 and total number of leaves are 92. Set the average daily temperature according to the Table 1.

34 leaves / 30 days =1.13 leaves per day

58 leaves / 40 days = 1.45 leaves per day

Table 1 : Effect of average daily temperature on leaf unfolding rate

Average daily temp (°F)	53	55	57	59	61	63	65	67	69	70	72	74	76	78	80	82
Leaves unfolded / day	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5

High temperature speeds up leaf unfolding rate and lowered temperature slows down leaf unfolding rate.

Physiology of bulb formation : Bulb acts as a storage organ required for initial growth and development of the plant. In early developmental stage, it supplies carbohydrates to shoots and flower buds. Before anthesis, it plays the role of both sink and source. Later on bulb becomes main sink and store carbohydrate for next season.

Physiological disorders :

Bud blasting and abscission : Bleaching of flower bud occur followed by necrosis on flower bud. The symptoms start appearing at the time when bud is 1.2-2.5cm in length followed by dropping of bud. The main cause of this disorder is low light intensity and short photoperiods. Shortage of water occurs at top of plant and competition for nutrients is created. Sometimes ethylene gas in green house is also a cause for this disorder. This can be prevented by supplying artificial light of about 450 watts/10 m^2 one month before flowering.

Leaf scorch/ leaf burn and tip burn : The white spots starts appearing on leaves and these spots later on become necrotic. This disorder occurs due to abrupt change in relative humidity. The bright sunlight after prolonged dull weather is cause of change in humidity. Besides this, high fluoride level in soil, water or air is also responsible. This can be controlled by foliar application of 1% $CaCl_2$ before visibility of buds (Selvaraj *et al.*, 2009).

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