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Achieving Year-Round Bloom: A Comprehensive Review of Flower Bulb Forcing Methods

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ABSTRACT

Flower crops are season specific and blooming period under traditional culture is short, varying from few weeks tot month, depending on the geographical location. This is one of the major limitations in floriculture subsector. The growers are forcing flower crops to produce flower during off season or predetermined time through manipulation of growing conditions to fetch good returns and increase the duration of availability in market. In some bulbous species such as tulip, narcissus, hyacinth, lilium etc. thermos periodic changes are required to induce flowering. The specificity of temperature requirement for different stages of flower initiation is manipulated for controlling the flowering. There are 3- phase forcing system for ornamental bulbs i.e. production, programming and greenhouse phase. There are two main techniques for programming underlying bulb forcing i.e. Rooting room Forcing and Non-rooting Room Forcing schedule. Hence, programmed blooming results in year-round availability of flowers for floriculture industry.

Keywords: *Bulbous, Flower, Forcing, Programming, Year-Round, Tulip and Narcissus.*

INTRODUCTION

A large number of cut flowers and pot plants are raised from underground parts (bulbs, corms, rhizomes, tubers, *etc.*) commonly referred to as 'bulbs' or 'geophytes'. A large number of bulbs are imported from Europe, especially The Netherland, which is also the biggest producer of flower bulbs in the world. In India, bulbs are normally grown in open conditions under varied climatic conditions. In temperate regions, the bulbs are planted in spring whereas in sub-tropical climates they are planted in winter. In tropical climates, bulbs can be planted the year round. In North America and Western European countries, the bulbs are forced to produce flowers at will, to match the demand during festivals, that is, Christmas, New Year, Easter, *etc.* The system by which the cut blooms or potted plants are produced from a storage organ is referred to as 'forcing'.

Flower bulb forcing can be defined as an operation in bulbous ornamental crops, after it reaches the ripeness-to-flower stage, in order to make it to flower at a specific date (e.g. on New Year's day, Christmas celebration, Valentine day, Deepawali, *etc.*), or during off-season period. These bulbous ornamental crops are programmed to flower earlier or later than the normal flowering season. It has been put forward that, after reaching a ripeness-to-respond stage, and upon receiving proper stimuli, flowering hormones, known hypothetically as vernalin and florigen, are produced which stimulate the initiation of flower primordium and subsequent blooming (Larson, 2012).

During the certain occasion (New Year, Christmas, Mother's Day, Memorial Day, Valentine Day, Graduation Exercise Day, *etc.*), the demand for cut flowers is generally very high Thus, farmers can fetch high prices by selling their produce on these specific dates.

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During the normal flowering season, there will be abundance of flowers afterwards; there will be insufficiency of flowers. The flowers which were harvested during peak flowering, either they were sold in very low prices or left on the plants. This leads to huge post harvest loss in loose and cut flowers. Thus, it would be beneficial for farmers to produce cut flowers during the off-season period to fetch higher price.

Objectives of bulb forcing in bulbous ornamentals

The main objective of flower bulb forcing is to avoid surpluses of seasonal cut flowers. Most of flowers produce flower only when they receive their favorable environmental conditions such as optimum temperature, photoperiods and light intensity etc. Thus large quantities of flowers are available, which will fetch low price and sometimes are not even sold. Flower bulb forcing is also done to avoid wastage or spoilage of surplus cut flowers. Flowers are most delicate and complex entity which is highly perishable with time. If the flowers are not sold in time the loss their market value or not even sold and left a waste. Flower bulb forcing is done to avoid danger of epidemics. Sometimes there will be pest and disease epidemics in flower crops due to favorable climatic condition which will cause severe monetary loss to the farmers. Flower bulbs programming is done to generate employment throughout the year. Flower production requires intensive labor. Most of labors will get employment during planting season, intercultural operations and harvesting of flowers crops by growing staggered crops throughout year. Flower forcing has potential in present scenario to double the farmers' income as off season produce will fetch higher price. As with modernization the demand and consumption of flowers are increasing and in order to meet the demand we import the flowers from other countries which creates the trade imbalance so by increasing domestic production of flowers during off season by forcing we can reduce the imports and can balance the trade. India is the land of festive occasions where the flowers are demanded every now and them. So, to meet the consumer's demand for specific dates, flower forcing has much to offer.

Physiology of flowering

The modifications from the vegetative to flowering resulted from the series of changes in morphogenesis and cell differentiation at the shoot apical meristem. The developmental signals that bring about changeover from the vegetative meristem to reproductive meristem include endogenous factors, such as circadian rhythms, phase change, and hormones, and external factors, such as day length (photoperiod) and low temperature (vernalization) (Bhatla and Lal, 2018). In the case of photoperiodism, transmissible signals from the leaves, collectively referred to as the floral stimulus (florigen), are translocated to the shoots apical meristem. Stem apex or leaves are signaled to produce flowering hormone, known hypothetically as vernalin after cold treatment which results in the initiation of flower primordium. Ultimately this process leads to the production of the floral organs-sepals, petals, stamens and carpels and subsequent blooming (Lucidos, *et. al*., 2013).

The flowering process in bulbous plants involves five successive stages:

- Induction
- Initiation
- Organogenesis (differentiation of floral parts)
- Maturation and growth of the floral parts, and
- Anthesis

The determinations of the period of the growth cycle during which these successive steps take place in the bulb are essential for flower bulb forcing.

Stages of floral initiation and development in bulbs

I Vegetative meristem-leaf forming stage
II Flower initiation-doming of meristem
Pr Flower primordia is noticeable (for bulbs with multiple flower, *e.g*. *Hyacinth* and *Lilium*
Sp Spathe initial visible *e.g*., *Narcissus*
Br Flowers bearing bracts, specialized leaves, visible *e.g*., *Lilium*
Bo Secondary bract
P1 Perianth, outer tepal initials visible
P2 Perianth, inner tepal initials visible
A1 Androecium, outer stamen initials noticeable
A2 Androecium, inner stamen initials noticeable
G Gynoecium (3 carpels) initials visible
Pc Corona initials visible *e.g*., *Narcissus* (Kodaira and Fukai, 2004)

Flower initiation in bulbous crops

Flower initiation in bulbous crops takes place at different seasons of the year and at different stages during the development of the bulb. They are as follows:

Narcissus forms the flowers during March and April. In case of tulips, crocus, iris, hyacinth, flower formation occurs after harvesting of bulbs during the storage period. In Iris, flowers are formed after replanting, at low temperature in winter or early spring. In case of lilium, *Begonia and dahlia,* formation of floral parts begins at end of the storage period. In *Anemone*, *Freesia*, Gladiolus, flowers are formed after replanting in spring whereas, in *Amaryllis belladona*, *Nerine* floral parts development takes more than a year before flowering. Floral parts formation occurs alternatively with leaf formation during bulb development. Examples: *Hippeastrum*, *Zephyranthus* (Bhattacharjee, 2006).

Thermoperiodic response of bulbous plants

Thermoperiodism is process in bulbous ornamentals which only flower after receiving a recurring periods of warm and cool temperatures.

Warm-Cold-Warm sequence: Bulbs that show their active vegetative and flowering in spring generally exhibit their rest period in summer, when temperatures are high and the soil is dry. They resumes their further growth in the autumn. This group of bulbs requires a warm-cold-warm cyclic period to express active growth and complete their life cycle.
Examples: *Tulipa, Daffodils, Hyacinth, Freesia etc*.

Cold - Warm - Cold sequence: Summer flowering bulbs need have an active growth during the summer. Their rest periods generally occur in winter, when the temperatures are low. They need a cold - warm - cold sequence of temperature to express active growth and complete their life cycle.
Examples: *Gladiolus* and *Lilium etc* (Khodorova *et. al*, 2010).

Effects of seasonal thermoperidism on growth and development of flower bulbs
Warm-Cold-Warm annual growing sequence

Species	Summer	Fall-Winter	Spring
Tulipa	Organogenesis	Rooting, Induction of scape elongation and bulbing	Flower stem elongation, flowering and bulbing
Freesia	Dormancy release	Organogenesis, Flowering, and bulbing	Rooting and scape elongation

Cold-Warm-Cold annual growing sequence

Species	Fall-Winter	Spring	Summer
Gladiolus	Dormancy release	Organogenesis, Rooting and beginning of growth	End of flower stem elongation, flowering, corm enlargement, cormel formation.
Lilium longiflorum	Dormancy release	Organogenesis (leaves, flowers and scales), stem elongation.	Flowering and bulbing

DeHertogh, 1974

Different phases in flower forcing of bulbous plants

The complete programme of bulb forcing has been divided in to four following phases:

1. Production phase: All the operations which are required for producing marketable bulbs are placed under production phase. The bulb production phase is further elaborated as following;

- Harvesting of bulbs, grading of bulbs into planting bulbs and marketable bulbs and storage;
- planting, rooting, and low temperature treatment for flowering
- leaf and flower stalk development
- flowering; and
- Bulb size enlargement and increase in numbers.

2. Programming phase: All the practices after harvesting of bulbs until placing of bulb under greenhouse conditions comes in this phase. Harvesting of bulbs, pre-planting storage for flower primordia initiation and rooting under cool moist condition are placed under this phase.

3. Greenhouse phase: In this phase, various environmental conditions such as temperatures, humidity, carbon dioxide, photoperiod duration, light intensity, fertilization, proper ventilation, hygiene, and pest are controlled. This phase includes planting of bulbs in the greenhouse where flower stalk elongation takes place.

4. Marketing Phase: In this phase, the development of plants is carried until the produce is ready for marketing. Forcers should always begin with marketing phase and subsequently manage the crop for the selected market starting with the production phase (Imanishi *et al.*, 2002).

Programming phase

During the programming phase, the bulbs are subjected to varying temperature treatments specific to the crops to facilitate the growth of floral organs. Two techniques, namely, 'Standard Forcing' and 'Special Pre-cooling' are used for completing the flowering process in many bulbous crops.

Techniques of programming phase

1. Standard forcing technique / Rooting Room forcing

In the 'Standard Forcing' technique, temperature is a major contributing factor, which controls flower initiation and development, mobilization of starch into sugars and growth of scape. The bulbs are placed initially at 9^{0}C in the rooting room then roots will initiate from these bulbs. Afterwards, the temperature is lower down to 5^{0}C until the shoots are above 5 cm. Then, growth of the shoots is checked at 0^0-2^{0}C (DeHertogh, 1992).

Concept of standard forcing technique

Developmental events	- bulb harvesting -Prior planting storage for development of floral parts	Planting and rooting under cool-moist condition	Low temperature treatment for flowering	Subsequent warm temperature treatment for flower stalk elongation and flowering

I. Forcing Tulip

Standard forcing tulips is done for producing cut flowers and flowering potted plants during off season. The flowering season make longer from late winter to early summer.

Tulip comes under warm-cool-warm temperature category. During the harvesting time, the apical meristem of tulip is in vegetative stage. Subsequently harvesting of bulbs, these are given warm temperatures for flower initiation and organogenesis.

Vegetative and reproductive stages of Tulip apex

Stage and Symbol Description of flower initiation and organogenesis with bulbs

I Vegetative apex
II Doming of apex immediately prior to flora parts initiation
P1 Development of first whorl of perianth (tepals)
P2 Development of second whorl of perianth
A1 Development of first whorl of androecia (stamens)
A2 Development of second whorl of androecia (stamens)
G Development of trilobbed gynoecium
(Kamenetsky and Okubo, 2012)

For early season flowering, bulbs of tulips are harvested in late summer and kept for 1 week at 34^{0}C. Afterward, they were given 17^0-20^{0}C to speed up flower initiation and organogenesis. When the floral bud reaches trilobbed gynoecium in rainy season, the bulbs are given regular pre cooling at 7^0-9^{0}C for 6 weeks before planting. This treatment enhances the further development of floral parts as well as the roots. After planting, the bulbs are rooted at two lower temperature first at 9^{0}C and then at 5^{0}C. The bulbs receive this cumulative cold temperature treatment for 15 weeks and bulbs are placed in green house temperature of 18^{0}C. For early forcing, plants may be extended in the dark until the lowest internode becomes visible. For midseason forcing is mainly done for getting flower for Valentine's Day. For this, bulbs are harvested during early rainy season and are kept at 17^0-20^{0}C to develop the floral parts. Then, bulbs are precooled at 9^{0}C for first week. For the cut tulips, bulbs are given 16-20 weeks cold treatment whereas for potted tulips, 14-16 weeks cold treatment is given. Afterwards these bulbs get 17^{0}C in the greenhouse. The late forcing is done for Easter. The harvesting of bulbs is done in rainy season and these bulbs are kept at 23^{0}C for one month and at 20^{0}C for another one month. The low temperature treatment (5^{0}C) for longer duration (12-14 weeks) showed the reasonable shoot growth and good flowering after planting. High temperature (21^{0}C) or a short period at 5^{0}C (2-6weeks), result in no flowering, however when flowering occurs, there is a slow shoot elongation (Moe and WickstrØm, 1973).

II. Forcing Narcissus

Standard forced Narcissus are programmed for pot plants or as cut flowers. The flowering season make longer from late winter to early summer.

Internal stage of development (ISD) scale for Narcissus

Stage and Symbol Description of flower initiation and organogenesis with bulbs

I Foliage leaf and bulb scale initiation; apex flat
II Apex broadened, thickened and dome shaped
III (Sp) Spathe initial visible
IV (P1) Perianth, outer tepal initials visible

V (P2) Perianth, inner tepal initials visible
VI (A1) Androecium, outer stamen initials noticeable
VII (A2) Androecium, inner stamen initials noticeable
VIII (G) Gynoecium (3 carpels) initials noticeable
IX (Pc) Corona initials visible

For early season flowering, bulbs of narcissus are harvested in rainy season and placed for 1 week at 34^{0}C. Afterward, they were given 17^0-20^{0}C to pick up the pace of flower initiation and organogenesis. When the floral bud reaches corona initials observable stage in August, the bulbs are precooled at 9^{0}C for 6 weeks prior to planting. This treatment enhances the further development of floral parts as well as the roots. After planting, the bulbs are treated at two lower temperature first at 9^{0}C and then the low temperature at 5^{0}C for rooting. The bulbs receive this cumulative cold temperature treatment for 15-16 weeks and bulbs are placed in green house temperature of 16-18^{0}C. For early forcing, plants may be extended in the dark until the lowest internode becomes visible. For midseason and late forcing, the harvesting of bulbs is done in early autumn and are kept at 17^0-20^{0}C to develop the floral organ within bulb. For the cut narcissus, bulbs are given 16-20 weeks cold treatment and 14-16 weeks cold treatment is given for pot narcissus, they are kept in a 13^0-15^{0}C greenhouse (Waithaka and Wanjao, 1982).

2. Special Pre-cooling technique / Non-rooting Room forcing
In the special precooling technique, the bulbs are pre-cooled and unrooted bulbs are directly planted in the greenhouse for rooting and development of flowers.
e.g. Amaryllis, Caladium, Calla Lily, Dahlias, Dutch Iris, freesias, Lilies, Lily of the Valley, *Oxalisspp*., Paperwhite Narcissus

Concept of special pre-cooling / Non-rooting forcing technique:

Phase	Programming		Greenhouse
Season	**Summer**	**Spring**	**Fall – Spring**
Developmental events	-Bulbs harvesting - Prior planting storage under for development of floral parts	Low temperature treatment for flowering	Subsequent warm temperature treatment for flower stalk elongation and flowering

III. Special pre-cooling technique for Forcing Lilium
Classification of dates of Easters

- For early easter: March 26, April 1
- For medium easter: April7, April 13
- For late easter: April 18, April 22

The exact handling of the bulbs on arrival will be determined by the dates of arrival of the bulbs and the date of Easter. There are 3 basic programming systems (for Ace, Harbor and Nellie White easter lily cultivars).
In Cooling prior to potting, *Lilium* bulbs are vernalized at 4.5-7.5^{0}C for 6 weeks prior to planting for uniform and rapid flowering.
In natural pre-cooling system, non-pecooled bulbs are planted immediately on arrival and grown under cool natural conditions but with frost protection, prior to placed in greenhouse (Larson, 2012).
In controlled temperature forcing technique, non-precooled bulbs are potted and placed in controlled temperature room at 0.5-7^{0}C for 6 weeks prior to being placed in greenhouses.

Programming Systems	Treatments	Temperature(^{0}C)	Duration
Cooling prior to potting (PC)	Bulb cooling (on arrival)	4.5-7.5	6 weeks (in moist soils)
Natural Cooling (NC)	Bulb cooling (after potting or in the field)	Outdoor during cold winter month	
Controlled Temperature Forcing (CTF)	After Potting Bulb cooling	17^{0}C 2-5^{0}C	2-4 weeks (in moist soils) 6 weeks
Greenhouse phase	Forcing (At bud visible stage)	17 ^{0}C 21^{0}C	Takes 35 days to flower Takes 28 days to flower

(Lee et al., 2010)

Plant Growth Regulators for Bulbs
1. Ancymidol: Ancymidol is effective for height control of pot tulips. It does not affect timing of the plants, flower size, or percentage of plants flowering.

2. Ethephon: It is effective for controlling the height of daffodil (Koksal, 2009).

Conclusion
Flowers which are available during the normal season are plentiful, thus fetching a low price. Sometimes the farmers have to sell their produce even at a loss. In some cases, flowers which could not be sold are either left on the plants or are spoiled after being harvested. Thus, flower bulb forcing makes it possible to produce cut flowers during the off-season period to obtain higher price, although the inputs may be higher. The demand for cut flowers is generally very high during certain occasions such as New Year, Christmas, Mother's Day, Memorial Day, Valentine Day, Graduation Exercise Day, *etc*. Thus, flower bulbs forcing will be to the farmers' advantage if they can produce cut flowers to be available on these specific dates.

The bulb growth and development are markedly affected by many environmental factors, with temperature generally being the most important. Numerous results on the effects of temperature are available and they are used in practice to control flowering. Very often, the research was conducted to determine the best temperature sequences during bulb storage and subsequent plant growth that would lead to the production of a cut flower or a potted plant with high commercial characteristics, e.g., flowering plant height. This practical approach has been an obstacle to detailed physiological and fundamental approaches on growth and development. A better understanding of the processes that determine flower induction and initiation, flower stem elongation, bulbing, etc., is still required for most genera and species. Such a fundamental understanding would be of great assistance for optimal control of bulb growth and development and flowering.

Future Scope of the Study

Research in major areas to achieve the year-round achievement of ornamental bulb is going on in the Netherlands and need to be done in major bulb producing countries in laboratories and greenhouse. The major areas include production of high-quality bulb, harvesting stage of bulbs at physiological maturity indexes, specific growing media for specific bulbous crops, high or low temperature treatment standardization for major ornamental bulbous crop, standardization of automation during production and programming phase and cost-effective programming procedure. The research related to marketing trend for schedule dates and their economic viability must be identified. Many improvements in technology will come from successful bioengineering of bulbs used for forcing. Clearly, innovative techniques that are easily adapted by the forcing industry will contribute markedly.

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Conflict of Interest

The author declares that there is no conflict of interest.

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