Flower Forcing: A Review

Abstract

In the modern floricultural industry, scheduling plant production is essential due to fluctuating market demands. Flower forcing, which stimulates flowering at specific dates or during off-season periods, is a key technique employed. The manipulated flowering dates resulting from flower forcing may deviate from the plant's natural schedule, occurring either earlier or later than the standard flowering dates.This can be achieved by adjusting factors affecting flowering such as temperature, photoperiod,and irradiance*etc.*Implementation of special practices like pruning, leaf trimming, dormancy breaking helps in forcing operation in certain plants. Utilization of chemicals such as plant hormones like gibberellin and ethylene, growth retardants and some fertilizers also play an important role in forcing.Advancements in plant physiology, photomorphogenesis, metabolism, and greenhouse technologies have led to the development of multiple strategies to finely regulate the rate of plant growth and development across various crops.

Key words: forcing, off-season, pruning, hormones

1. Introduction

Flowers that are abundant during their typical season tend to have a lower market value due to their widespread availability. At times, farmers find themselves compelled to sell these flowers at a loss or risk having them go unsold. Unfortunately, some harvested flowers are left to spoil, with certain blooms even left on the plant when the cost of harvesting outweighs potential profits. This results in significant financial setbacks for the farmers. Therefore, it is recommended that farmers consider cultivating flowers during off-season periods to mitigate losses and secure higher prices for their produce, even though the associated costs may be higher.

Likewise, there is a substantial demand for flowers during specific events likeValentine's Day, Christmas, Mother's Day, New Year's Day, Memorial Day, Graduation ceremonies, Onam, and others. Therefore, it would be favourable for farmers to cultivate cut flowers specifically to meet the heightened demand during these occasions.

Flower forcing refers to any post-ripeness operation or treatment applied to a plant to induce flowering that would not naturally occur, typically at a specific date or during off-season periods. These manipulated flowering dates may deviate from the plant's usual, occurring either earlier or later than the standard flowering dates or periods(Chomchalow,2004).

1. 1 Objectives of forcing

- To prevent an excess of in-season flowers: it is common for most cut flowers to be cultivated during their respective seasons when favourable conditions for production prevail. Consequently, the abundance of these flowers leads to a lower market price, and in some cases, they may even become unsalable.

- To prevent the wastage or spoilage of excess flowers: it is important to note that flowers, unlike many other products, are perishable. If not utilized or sold in a timely manner, they tend to spoil or become waste.
- To mitigate the risk of epidemics: in-season flower production is susceptible to various insect attacks and disease outbreaks, mainly because the prevailing climatic conditions create a favourable environment for their proliferation.
- To ensure year-round employment opportunities: cut flower production, which demands significant labour input, often faces peak season concentration of labor activities. Off-season cut flower cultivation plays a crucial role in distributing employment opportunities across the entire year, contributing positively to the nation's economy.
- To enhance the income of farmers: it is evident that selling products in high demand contributes to higher earnings.
- To minimize imports and maintain a balanced trade: florists often resort to importing cut flowers from abroad during specific periods when domestic production is not feasible, at a higher cost. The cultivation of off-season cut flowers, or those produced during specific periods, serves to mitigate the need for imports, contributing to a more balanced trade.
- To satisfy the customers at the time of demand:the requirement for cut flowers is not confined to specific seasons but spans throughout the year, contingent on particular occasions. Off-season cut flowers, or those produced at certain specific periods, are to please the customers at the time of their requirements.

2. Flowering behaviour of plants

Plants can be categorized into two groups based on their genetic makeup:(i) those that flower all year round, and (ii) those that flower only in-season.

2.1 All year-round: There are two categories of plants within this group, distinguished by the extent to which they are influenced by the season, namely:

(a) Little or no seasonal influence: Flowering takes place continuously throughout the year with minimal impact from seasonal variations. Examples: roses, heliconia, marigold, *etc.*

(b) Great seasonal influence: Flowering in this type of plant is significantly influenced by the season. There are periods of abundant flowering due to favourable climatic conditions, while in other times, flowering is less prolific because the weather conditions are not optimal. Examples:dendrobium orchid, jasmine, *etc.*

2.2 Seasonal: These are plants that bloom during particular seasons, also known as in-season plants. Within this category, there are two distinct types of plants:

(a) Temperature Influenced: These are plants whose flowering is impacted by the temperature, particularly low temperature. Examples: tulip,amaryllis, daffodil, narcissus, *etc*. which will flower upon exposure to low temperatures.

(b) Photoperiodic Influenced: These are plants whose flowering is impacted by the photoperiod. Photoperiodic flowering responses can be divided into following response groups:

Short-day plants – type of plants whose flowering is triggered by shorter periods of daylight

Long-day plants – type of plants whose flowering is triggered by longer periods of daylight

Day-neutral plants – plants whose flowering is not significantly affected by day length. They are capable of flowering regardless of the length of daylight they receive.

3. Physiology of flowering

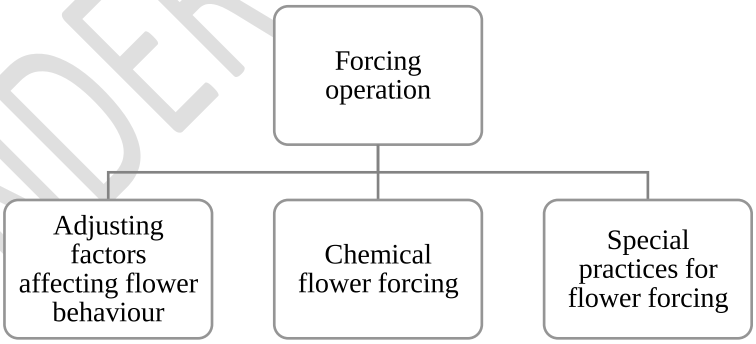
Flower induction involves both endogenous (internal) and exogenous (external) signals that bring about changes in the plant's developmental program. In reaction to these signals, a chemical stimulus is transmitted to the meristematic tip, which undergoes alterations, resulting in the production of flowers instead of leaves. This process is known as floral evocation. Following floral evocation, there is the subsequent formation of flower buds, referred to as flower initiation, and the progression into flower or inflorescence development (Proietti, 2022).

Flowering, as a developmental stage, can be characterized as the shift from vegetative growth to reproductive stage. This transition is evident through changes in the properties of the shoot apical meristem, which ceases the production of leaves and initiates the generation of floral meristems responsible for the formation of flowers.

Once the plant reaches this "ripeness-to-respond stage" and is exposed to suitable stimuli, it produces floral primordium through the generation of hypothetical substances. If triggered by appropriate temperature, these substances are termed 'vernalins,' and if prompted by proper photoperiod, they are referred to as 'florigen.' The floral primordium subsequently develops into a flower, which will bloom at a later time, influenced by these environmental factors.

4. Forcing operation

Flower forcing can be done by the following ways:



4.1 Adjusting factors affecting flower behaviour

There are four primary external environmental cues that affect flowering in plants: photoperiod, temperature, irradiance, and stress (Erwin, 2005).

4.1.1 Photoperiod

The natural cycle of day length over a 24-hour period directly influences the flowering behaviour of plants, a phenomenon termed "photoperiodism." This response to light duration can be altered by either adding artificial light from sources such as fluorescence lamps andtungsten bulbs to extend daylight hours or by limiting exposure to light by placing the plants in darkness, effectively reducing daylight duration.

Main objectives of adjusting photoperiod

a. Trigger flowering by providing the ideal photoperiod:Supplying additional light to a long-day plant beyond its critical photoperiod induces flowering.
b. Maintain the plant in a non-inductive cycle, preventing it from flowering: By supplying additional light to a short-day plant beyond its critical photoperiod, flowering is inhibited, and the plant remains in the vegetative phase.

4.1.1.1 Creating artificial short days

In situations where the natural day length is lengthy, the primary method to establish a short photoperiod within a greenhouse is by employing opaque materials that prevent light penetration. These materials, commonly known as "black cloth" or "blackout cloth," effectively block out sunlight, creating a darkened environment within the greenhouse.Growers can manually pull black cloth over plants at a predetermined time in the afternoon to shorten the natural day length. Alternatively, growers can opt to install automatic blackout curtain systems in their greenhouses. These systems are equipped with motorized mechanisms that can enclose individual benches or the entire greenhouse with blackout curtains. By programming the system, growers can automatically regulate the duration of daylight exposure for their plants.

Sangma *et al.* (2016) studied the influence of different covering materialson off-season cut flower production of chrysanthemum. Result of the study revealed that plants under HDPE (High- Density Poly Ethylene) recorded the optimum plant height, highest number of cut stems, plant spread, earliest flowering. As its effectiveness in creating artificial short days, lighter in weight and easier to handle can be recommended as replacement to tarpaulin.

4.1.1.2 Creating artificial long days

According to Currey and Lopez (2012), under natural condition long days can be created by the following ways; Day-extension (DE): lighting at the end of the day, Night-interruption (NI): lighting at the middle of the day, or by cyclic lighting: intermittent photoperiodic lighting.

Thakur and Grewal (2019) investigated the utilization of photoperiodic night interruption to optimize the timing of flowering in Chrysanthemum cultivar Anmol,aiming to synchronize it with the market demand. The effect of six-night interruption treatments (*i.e.*, control, <5 second flash, 30, 60, 90, 120 min) were monitored.The onset of flowering was notably delayed, spanning from mid-December to the end of February, encompassing a duration of approximately two months. Moreover, there was an observed increase in the number of flowers per plant as the duration of night interruption escalated from the control condition to 120 minutes.

Incandescent light bulbs (INC), Compact Fluorescent Lights (CFL), high-intensity discharge lamps (HID) or light-emitting diodes (LED) *etc*. can be used for lighting in green house for controlling photoperiod.

Matysiak (2021) reported that LED lighting technology enables the cultivation of high-quality potted roses within greenhouses even under unfavourable light conditions.

Additionally, it aids in suppressing the development of powdery mildew caused by *Podosphaerapannosa.*

Strategic utilization of LED lighting presents opportunities for enhancing the efficiency of year-round chrysanthemum cultivation by bypassing the plant's natural requirement for short days to induce flowering(Sharathkumar*et al.* 2021).

4.1.2 Temperature

Certain plant species necessitate exposure to low temperatures for flower induction, requiringfulfilment of a specific cold requirement. To accommodate the needs of these low-temperature-requiring plants, adjustments can be made by storing plant parts, typically bulbs or seeds, in refrigerators or freezers. The duration of sensitivity to thermal stimuli varies across plant species.

The exposure to low temperature to induce floweringis known as vernalization.Winter annuals exhibit a facultative vernalization response, indicating that while flowering doesn't necessarily hinge on cold exposure, the process is expedited following a period of chilling.Biennials possess an obligate requirement for cold treatment, meaning they cannot initiate flowering without prior exposure to cold temperatures.Plants that necessitate vernalization experience delayed or inhibited flowering in the absence of cold exposure. Typically, these plants adopt a rosette growth pattern instead of initiating flowering(Taiz and Zaiger, 2006).

Exposing bulbs of Liliumcultivar 'White Heaven' to 4°C for one week resulted in a 20 per cent reduction in the time required for floral transition(Martin *et al.,* 2015). Similar results were reported by Mazor (2021) in *Lilium candidum.*

4.1.3 Irradiance

In general, increased irradiance shorten the juvenile period in many plant species. Plants are divided into two based on response to irradiance i.e., Facultative irradiance response and Irradiance indifferent.

Baloch *et al.* (2012) conducted a study to investigate the effect of varying irradiance levels on the flowering time of facultative long-day ornamental annuals, including Moss rose cv. Sundance, Snapdragon cv. Coronette, Pansy cv. Baby bingo, Annual verbena cv. Obsession and Petunia cv. Dreams. Saplings of each cultivar were transferred into four light intensity chambers for 8 hours daily. The results revealed that facultative long-day plants treated with high irradiance levels (92 and 119 $\mu molm^{-2}s^{-1}$) exhibited earlier flowering.

4.1.4Stress

Extended exposure to high temperatures cansuppress flowering in certain plant species. Warner and Erwin (2002) reported that*Impatiens hawkeri* and *Viola x Wittrockiana* experienced a decrease in photosynthetic rates for up to three days after just two hours of exposure to high temperatures (35°C), compared to unstressed plants.

Hedge *et al.*(2020)revealed thatflowering of long-day spring flowers such as Arabidopsisis increasedunder high temperature conditions. Conversely, the induction of short-day autumn flowers like chrysanthemum is decreased when exposed to high temperatures.

4.2 Chemical flower forcing

4.2.1 Fertilizers: Certain fertilizers can influence the carbon-to-nitrogen (C/N) ratio of plants, consequently impacting their flowering behaviour. A higher C/N ratio, indicating higher carbon content, tends to induce flowering, whereas a lower C/N ratio, reflecting lower carbon content, tends to maintain the plant in a vegetative phase. Adjusting the formula of fertilizers can be employed to either delay or promote flowering, offering a means to manipulate the plant's developmental stage according to desired outcomes.

Tsai and Chang (2022) reported that high C/N ratio could boost spiking and flowering and low C/ N ratio might suppress spiking and therefore flowering in phalaenopsis orchid.

4.2.2 Plant Hormones: There are mainly two plant hormones that affect flowering, namely:

a) Gibberellins: It exhibit a distinctive capability among plant hormones by stimulating significant growth in intact plants. Research has shown that gibberellins can serve as a replacement for the long-day requirement in certain species. Additionally, they can bypass the need of vernalization in certain plants. It seems that the formation of flowers triggered by either long days or cold periods may typically rely on the accumulation of endogenous gibberellins during these periods. This is supported by observations indicating an increase in gibberellin content in affected plants following such treatments.

The application of GA3, throughdipping of rhizome or foliar spray, has been found to stimulate flowering inornamentals belonging to the Araceae family(Chen *et al.,* 2003).

Rani and Singh (2013) reported that GA3 application @ 150 mg L^{-1} resulted in advance flowering and long-lasting flower spike in tuberose. Prajwal.Sajid *et al.* (2016) conducted an experiment to study the effect of gibberellic acid on inducing flowering time in *Chrysanthemum morifolium.* Result of the study showed that application of GA3 @ 250 mg L^{-1} produced flowers too early than the normal season and extended the flowering period.

b) Ethylene: Ethylene is the sole naturally occurring plant growth hormone found in a gaseous state, notable for its effectiveness in initiating flower development.

Exogenous ethylene, whether in the form of gaseous ethylene or ethylene-releasing substances like ethrel, has found extensive use in inducing flowering among bromeliads. It plays a pivotal role in synchronizing and expediting the flowering process in these plants.Contrarily, some ethylene synthesis inhibitors such as amino-oxy acetic acid, silver thiosulfateand amino ethoxy vinyl glycine (AVG)exhibit potent activity even at low concentrations.These inhibitors are recognized for their ability to disrupt flower induction, leading to a considerable delay in flowering among Bromeliaceae plants(Iqbal *et al.,* 2017).

4.2.3 Growth retardants:

These synthetic chemicals inhibiting stem elongation and resulting in overall stunting of plant growth. This effect is achieved in part by their inhibition of gibberellin synthesis. Examples of these chemicals include Phosphon D, MH (Maleic Hydrazide), Amo-1618,Cycocel, and Ancymidol. Growth retardants like CCC facilitate the initiation of floral primordia by either diminishing the levels of endogenous gibberellins or counteracting their inhibitory influence on floral initiation.

A study conducted by Vaghasia and Polara (2015)on impact of plant growth retardants on the growth, flowering, and yield of chrysanthemum cv. IIHR-6. The results of the study revealed that foliar application of MH at 700 mg L^{-1}, administered one month after transplanting, yielded superior flowers compared to all other growth retardant treatments.

4.2.4 Other Chemicals: Indeed, there are several other chemicals utilized to induce flowering in plants. These include potassium chlorate and its related compounds potassium nitrate, sodium chlorate,thiourea, and cultar(paclobutrazol). When applied as a soil drench or foliar spray, these chemicals can stimulate flowering in many ornamental plants.

Albethani and Aamry (2019) studied the effect of Cultar on growth and flower production of Ranunculus.The results showed that the cultar at 10 mgL^{-1} increased the yield and gave the longest flowering period.

4.3 Special practices for flower forcing

4.3.1 Selection of cultivars: Selecting the appropriate cultivars is crucial for achieving successful offseason cultivation. Chrysanthemum cultivars categorized in the 8-9 weeks response group thrived in regions or seasons with high light intensity, whereas those belonging to the 12-14 weeks response group were preferred for areas or seasons characterized by low light radiation. Photo-thermo insensitive varieties of chrysanthemum such as Pusa Anmol and Sensation offer the advantage of year-round flowering potential without requiring photoperiodic manipulation.

4.3.2 Pruning: Pruning serves as both an economical and practical method, not only for managing plant growth but also for commercial purposes, particularly in responding to fluctuations in demand for flowers across different seasons. This technique offers a straightforward means to regulate both the quantity and quality of flowering.

Hassanein (2010) conducted an experiment aimed at enhancing the quantity andquality of winter season flowering in roses (*Rosa spp.)* by modifying the timing and method of pruning applied during the autumn season. Result of the study revealed that the most effective treatment for enhancing flowering in a short period is light pruning of rose shrubs three weeks after the beginning of autumn, specifically during the third week of October.

4.3.3 Leaf trimming

In certain plants such as jasmine, leaves can act as inhibitors to flowering. Therefore, removing some leaves or a portion of a leaf can help induce flowering in such cases.

According to Srilatha *et al.* (2018), pruning jasmine cultivar Gundumalli to a height of 50 cm from ground level, coupled with foliar spray of 5% potassium nitrate, enhances the plant's nutritional status, promotes vegetative growth, triggers advance flowering, extends the longevity of flowering, and ultimately increases productivity.

4.3.4 Breaking Dormancy

Certain plants have seeds and buds that remain in a dormant stage, displaying no growth for a period of time. Breaking this dormancy can be achieved through various methods, including subjection to low temperatures or treatment with chemicals and gibberellins. Among these methods, gibberellins are commonly employed, particularly in relation to flowering. Applied gibberellins effectively break the dormancy of numerous seeds requiring cold conditions and induce flowering in many plants that require cold stimuli.

Natural termination of dormancy can be a prolonged process, but it can be artificially expedited through various methods. These methods include stratification (low temperature treatment), scarification, and the use of chemicals, including plant growth regulators, depending on the type of dormancy present.

Sajjad *et al*. (2020) reported that BAP and GA_3 was useful toalleviate corm dormancy of gladiolusin relatively short time.

5. Forcing of some flowers

5.1 Marigold (*Tagetes erecta*):Marigold is a day neutral plant. Flowering occursthroughout the year. It normally takes 60-70 days from sowing to harvest.The flowering time can be controlled by setting the seeding date approximately 60 to 70 days before the intended date of harvest. The recommended period for seeding is typically around 65 days prior to harvest.

5.2 Lotus (*Nelumbo nucifera*):Flowering behaviour of lotus is all year round, but it requires standing water. Forcing operation in lotus plant varies according to the season.

To counteract the reduction in blooming caused by low winter temperatures, it is advisable to lower the water level to 50 cm. This helps raise the water temperature, ensuring that blooming remains consistent with the summer season in terms of both quantity and size of flowers.To avoid the accelerated growth and early blooming of lotus plants caused by high summer temperatures, it's recommended to raise the water level to 75 cm from the original 50 cm level during winter. This adjustment helps reduce water temperature, ensuring that the amount of blooming and the size of flowers are maintained. To accommodate the potential increase in water level due to rainfall, it's advisable to maintain the water level at 50 cm. This allows for the incorporation of additional rainwater without disrupting the blooming process, ensuring that blooming remains unaffected.

5.3 Jasmine (*Jasminum sambac*):The flowering behaviour of jasmine typically exhibits peak blooming from March to June, with flowering continuing until October. However, there's a lean period from November to February, characterized by significantly reduced flower production and poor flower quality.

Advancing the pruning of plants to September, as opposed to the conventional practice of pruning at the end of November, has yielded significant benefits. This alteration has led to flowering during the lean winter season, November to February, with increased yield and improved quality. The average yield during the winter season saw a remarkable 2.67 times increase compared to November pruning. Moreover, the benefit-cost ratio (BC ratio) has improved substantially, reaching 2.51, compared to 1.66 in the conventional practice. Overall, this shift in pruning timing has enhanced profitability for farmers[IIHR, 2020].

5.4 Roses (*Rosa hybrida*)

Even though rose flowers all- year round, profuse flowering occurs during cool season. To achieve blooming during the Christmas to New Year period, it's recommended to cut the branches in November. Flowering typically occurs 43 days after pruning, aligning with the desired Christmas to New Year's blooming period. To further stimulate flower bud initiation for a bloom on February 10th, it's advised to cut the flowers on December 23rd, with flowering typically taking 49 days after cutting.

5.5 Gladiolus (*Gladiolus grandiflora*):In cooler climates, inducing flowering in gladiolus plants can be achieved by preheating corms before planting for two weeks at temperatures ranging from 27 to 32°C. This process forces the corms to flower early.

In warmer climates, a different approach is recommended. Soaking corms in a gibberellic acid (GA) solution, typically ranging from 10 to 25 ppm, before planting can accelerate flowering. This process works by hastening the differentiation of flower primordia, thereby promoting earlier blooming.

Conclusion

Flower forcing is a valuable technique in floriculture that enables growers to manipulate the timing of flowering to meet market demands, extend the growing season, and enhance the availability of flowers.This practice is essential for commercial flower production, ensuring a steady supply of blooms for various occasions throughout the year and maximizing profitability for growers.

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