JUST AGRICULTURE
multidisciplinary e-Newsletter

Regulation of Flowering in Flower Crops: A Review

[1]Swati, [2]G O Manjunatha and [3]R M Hosamani
[1]M. Sc. (Agri.) student, [2]Professor of Horticulture, [3]Professor of Horticulture
Department of Horticulture
College of Agriculture, University of Agricultural Sciences, Dharwad, India.

ARTICLE ID: 43

Abstract:

Flowering regulation holds immense practical value, especially in producing flowers during off-seasons, a process known as "forcing." By adjusting climatic factors, mechanical methods, and chemical treatments, flowers can be cultivated to bloom at specific times, such as during festivals like Diwali, Christmas and New Year. This technique helps synchronize flower production with market demand, ensuring continuous supply throughout the year and benefiting both producers and consumers. Off-season flower production can be enhanced through pruning adjustments, the use of plant growth regulators and regular fertilizer applications. Forced cultivation not only increases farmers' incomes by enabling the production of flowers when demand is high but also provides consumers with year-round access to flowers. The cut flower industry is increasingly shifting towards extended cropping seasons and off-season production, as altering flowering times ensures high-quality yields during peak periods like festivals and weddings. Recent research highlights the role of genes, environmental factors like vernalization, temperature and photoperiod and the application of growth regulators in controlling flowering time and plant vigor. Understanding these factors is crucial for optimizing harvest time, preventing market oversupply and improving the quality of floral produce.

Key words: flower regulation, light, temperature, plant hormones.

Introduction

Flowers have always played a significant role in our culture and society. Initially, people worldwide cultivated flowers primarily for their aesthetic appeal. However, with the advent of globalization and a free-market economy, the cultivation of flowers has evolved into a thriving industry. Today, cut flowers and potted plants are among the most commercially produced and exported ornamental plants, transforming traditional agricultural practices into more profitable ventures (Nazki and Wani, 2018).

JUST AGRICULTURE multidisciplinary e-Newsletter

The global floriculture industry, which is largely export-driven, is growing at a rate of 15% annually, with cut flowers representing its most substantial segment, accounting for up to 60% of world trade. This is followed by the production of potted plants, dried flowers, and ornamental plants (Anumala and Kumar, 2021). In 2017, the floral industry's market size was estimated at around 74 billion USD, with Europe and Asia being prominent contributors, accounting for 18% and 23% of the market, respectively (Anonymous, 2018; Parente *et al*., 2021).

Europe leads in global cut flower sales, holding a 31.0% share of the market value, followed by China (18.6%) and the USA (12.5%) (Darras, 2021). The leading producers of commercial cut flowers include the Netherlands, the USA, Colombia, Kenya, Zimbabwe, Japan, and Israel. In 2018, the Netherlands accounted for a 43.8% share of international exports, followed by Colombia, Germany, Italy, Ecuador, and Kenya. The Netherlands also ranks first in cut rose imports, holding a 20.7% share (Anumala and Kumar, 2021).

Flower regulation is an operation or treatment to the plant after reaching its maturation to respond stage in order to stimulate it to flower at a specific date than its normal blooming season. Before a plant can flower in response to its environment the organs that detect the environmental change, that condition called as maturation to respond stage. In 1901, Nicolas Dames introduced the system for "early flowering" in Hyacinths (Chandel *et al*., 2023).

In this article, we provide a concise overview of the latest information on flower regulation, covering various influencing factors. These include environmental factors such as ambient temperature, light and photoperiod; chemical factors like the use of growth regulators and other chemicals; physical factors such as pruning, pinching, thinning, planting time, mulching and the size of propagules; and genetic regulation.

Need of flower regulation

- Off-season production.
- To distribute employment throughout the year.
- Specific date production.
- To avoid surplus of in-season cut flowers.
- To avoid wastage or spoilage of flowers.
- To avoid danger of epidemics.
- To increase farmer's income.

- To reduce imports and balance of trade.
- To satisfy the customers at the time of needs.

Table 1: Flowering seasons of important flowers

SI. No	Crop	Normal season of flowering	Off-season
1.	*Jasminum sambac* *Jasminum grandiflorum* *Jasminum auriculatum*	February – June June - September May - September	July – January October - May October - April
2.	*Rosa centifolia*	March - October	November - February
3.	Tuberose	February - October	November - January
4.	Chrysanthemum	September - February	March-August
5.	Carnation	February - April	June - August
6.	Gerbera	October - December	April - June

Physiology of Flowering

A) Flowering hypothesis

Before a plant can flower in response to environmental factors like temperature and day length, its organs responsible for sensing these changes, typically leaves or meristems, must first reach a state called reactive maturity. It has been hypothesized that once plants achieve this maturity and are exposed to the appropriate stimuli, they initiate the production of flowering buds through the formation of hypothetical substances. These substances are thought to transform into 'vernalin' when exposed to the correct temperature and into 'florigen' when exposed to the proper photoperiod. This process ultimately leads to the development of blooming flowers (Singh *et al.*, 2023).

B) Factors affecting flowering

- **Temperature:** Temperature, especially low temperatures, plays a crucial role in flowering. For instance, winter wheat will not bloom unless it has been exposed to cold conditions. Similarly, the colored bracts beneath a poinsettia flower do not turn red in high temperatures. Temperature is particularly effective in triggering the flowering of bulbs, especially those that develop flower clusters during storage after a summer harvest and before being transplanted in autumn. For example, tulips and irises can have accelerated flowering when exposed to low temperatures (9-13°C), but prior treatment at higher temperatures (20-30°C) is essential for the flowering process.

JUST AGRICULTURE multidisciplinary e-Newsletter

- **Photoperiod:** This is a day-long cycle within 24 hours. The ability of plants to flower in response to day length is called photoperiodism. Plants can be classified into short-day, long-day and mid-day plants. Short-day plants are plants whose flowering occurs when the day length is shorter than a critical value (any number of daylengths per day). Long-day plants, on the other hand, are plants that flower when the day length is longer than a critical value. Day-neutral plants are plants whose flowering is not affected by day length.

C. Flowering behavior of plants:

- **All-Year Round:** There are two types of plants in this group based on how much the season can influence, namely:
- **Little or no seasonal influence:** Flowering occurs all year round with little or no influence of the season. Examples are roses, marigolds, chrysanthemums, and heliconia.
- **Great seasonal influence:** The season greatly influences flowering in this type of plant. There is a time when flowering occurs profusely due to favourable climatic conditions, and at other times, not quite profusely, simply because the weather is not optimum. Examples are jasmine, Dendrobium orchids, etc.
- **Seasonal:** These are planting that flower during specific seasons (i.e., inseason).

Techniques of flower regulation

- Manipulating environmental factors
- Chemical flower forcing
- Mechanical flower forcing
- Genetic intervention in flowering

Manipulating environmental factors

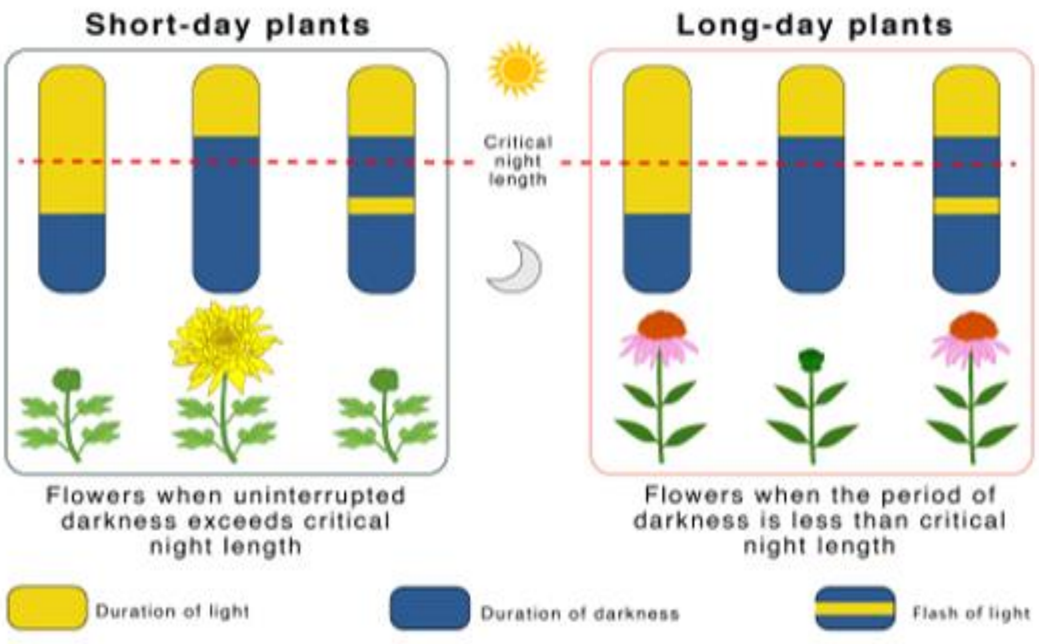
- **Photoperiod**
- **Temperature**

Classification of plants based on different photoperiod

- **Short day plants (SDP):** These plants require a relatively short-day light period (8-10 hours) and a continuous dark period of about 14-16 hours for subsequent flowering. Example: Chrysanthemum, Poinsettia, Cosmos, Zinnia

JUST AGRICULTURE
multidisciplinary e-Newsletter

- **Long day plants (LDP):** These plants require a longer day light period (usually 14-16 hours) in a 24 hours cycle for subsequent flowering. Example: Carnation, Bellflower (Campanula)



- **Day neutral plant (DNP):** These plants flower in all photoperiods ranging from 6 to 24 hours continuous exposures. Example – sunflower, rose

Photoperiod regulation techniques to create long day

During natural short-day conditions, long days can be created by three different methods;

- **Day-extension** - by giving supplemental lighting immediately after the sunset.
- **Night-interruption** - by providing artificial lighting during the midnight
- **Pre- dawn lighting** - Providing lighting from 2 am until sunrise

Light sources used in photoperiod regulation

Incandescent (INC), CFL (compact fluorescent light), halogen bulb, metal halide and LED (light emitting diode) bulbs.

- For flower induction of long- day plants, light from incandescent bulbs has traditionally been used at low intensities.
- Incandescent bulbs are effective at providing long days but they consume a lot of energy and are being phased out of production.
- Alternating compact fluorescent bulbs with incandescent lamps can save on energy costs yet still promote flowering in a wide range of long-day plants.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Table 2: Effect of photoperiod on flower regulation of flower crops

SI.no	Plant species	Plant type	Photoperiod	Flowering	References
1	Chrysanthemum	SD	SD+ NI 4h	Early	Oda *et al.*, 2012
2	Cymbidium	LD	SD 9h	Late	Kim *et al.*, 2012
3	Bugle lily	Obligate LD	LD 16h	Increased flowering	Thompson *et al.*, 2011
4	Yellow bells	-	LD (14 h)	Early	Torres and Lopez, 2011
5	White petunia	Facultative LD	SD 9h	Late	Warner, 2010
6	Mealy bug sage	LD	LD 18 h	Early (40-50 days)	Mattson and Erwin, 2005
7	English lavender	LD	SD 8 h	-	Monaghan *et al.*, 2004
8	Kalanchoe	SD	9-12 h	Early 100% flowering	Garner and Armitage, 2008
9	Easter lily	-	Natural light	Late (91.8 days)	Ei-Sawy *et al.*, 2021
10	Rainbow pink	LD	SD 9 h	Late	Park *et al.*, 2013
11	Scarlet sage	-	SD + 4-h NI	Early	Hong *et al.*, 2014
12	Dahlia	-	SD 9 h	Flowering at 41 days	Meng and Runkle, 2014

Role of temperature in flower regulation

Ambient temperature regulates flowering time by influencing the rate of growth and development throughout a plant's life cycle. Variations in temperature lead to physiological and developmental changes, such as leaf unfolding, flower initiation and flower development. Each plant species requires specific temperatures to reach certain phenological stages.

The coloured bracts beneath the poinsettia flower do not turn red at high temperatures. Temperature is particularly effective in initiating the flowering of bulbs, especially those that develop flower clusters during storage after the summer harvest and before being transplanted in autumn. In tulips and irises, flowering can be accelerated at low temperatures (9-13°C), but pretreatment at higher temperatures (20-30°C) is necessary for flowering.

Low-temperature induction is a primary trigger for flowering in most plants, and changes in environmental conditions ultimately regulate flowering through substances in the leaves known as 'florigen.' Plants begin the transition from vegetative growth to reproductive growth under the influence of low temperatures, a process known as vernalization. The FLC gene plays a crucial role in this floral transition by encoding a MADS-box transcription factor.

Vernalisation

- Latin word vernus – of the spring
- Promotion of flowering after exposure to cold
- The complete flowering of Campanula 'Birch Hybrid' was achieved after a five-week vernalization treatment at 2.5–7.5 ºC or after a nine-week treatment at 0–12.5 ºC.
- The temperatures producing the greatest flowering response in *Veronica spicata* L. 'Red Fox' and *Laurentia axillaris* were -2.5 ºC and 5–10 ºC, respectively.

Table 3: Effect of temperature on flower regulation

SI. no	Plant species	Temperature range	Flowering	Reference
1	Chrysanthemum	>20 ºC	Late	Nakano *et al.*, 2015
2	Lilium	2.5-7.5 ºC (Bulb)	Early	Suh *et al.*, 2013
3	Cyclamen	20 ºC	Early	Oh *et al.*, 2013
4	Rose	36 ºC/ 28 ºC (D/N)	Early	Greyvenstein *et al.*, 2014
5	Orchid	18-23 ºC	Early	An *et al.*, 2017
6	Tulip	7 ºC for 70 days	Early	Khan *et al.*, 2006
7	Narcissus	>25 ºC	Early	Noy-porat *et al.*, 2013
8	Petunia	26 ºC	Early	Warner, 2010

Chemical Flower Forcing

Four types of chemicals affect flowering, namely fertilizers, plant hormones, ethylene and other chemicals.

a) **Fertilizers**: Certain fertilizers influence the carbon-to-nitrogen (C/N) ratio in plants, which in turn impacts flowering. A broader C/N ratio, with higher carbon levels, tends to induce flowering, whereas a narrower C/N ratio, with lower carbon levels, keeps the plant in its vegetative phase. By adjusting the fertilizer composition, flowering can be either stimulated or delayed.

- **Retarding flowering:** This can be done by providing fertilizers having high amounts of N to the plant. Watering should also be provided so that N will be readily absorbed by the plant.
- **Stimulating flowering**: This can be done by giving fertilizers having low amounts of N and reducing watering. Other chemicals that help to fix N to a bound form can also stimulate flowering.

b) **Plant Hormones:** Two main types of plant hormones influence flowering, with gibberellins being one of them. Over 50 gibberellins have been identified in fungi and plants, all of which can be referred to as gibberellic acids, or GA. Gibberellins are unique among plant hormones in their ability to stimulate significant growth in intact plants. Research has shown that gibberellins can substitute for the long-day requirement in some species and interact with light. They can also eliminate the need for an inductive cold period (vernalization) in certain species for flowering. It appears that the formation of flowers, whether triggered by long days or cold periods, may normally depend on the accumulation of endogenous gibberellins during these times, as gibberellin levels increase in some affected plants following such treatments.

c) **Growth retardants**: These are a group of synthetic chemicals that inhibit stem elongation and cause overall stunting by partially inhibiting gibberellin synthesis. Examples include Phosphon D, Amo-1618, CCC (Cycocel) and Ancymidol. Growth retardants like CCC promote the initiation of floral primordia by reducing endogenous GA levels or counteracting its inhibitory effects on floral initiation.

d) **Ethylene:** Ethylene is well-known for its ability to induce flowering in pineapples. Applying acetylene, a precursor to ethylene, to the top of a pineapple plant is highly effective in triggering flowering. A commercially available ethylene-releasing substance, known as ethephon or ethereal, is also used for this purpose. Interestingly, ethylene can induce flowering in mangoes and bromeliads, which is unusual since the gas typically inhibits flowering in most other species.

e) **Other Chemicals:** Several other chemicals are used to induce flowering. These include the explosive potassium chlorate and its related compound sodium chlorate, potassium nitrate, thiourea, paclobutrazol (commercially known as culture), etc.

Mechanical flower forcing

Pruning, leaf trimming, breaking dormancy, manipulation of date of planting, low-temperature storage and pinching.

1. **Pruning:** Pruning helps broaden the C/N ratio which promotes flowering. This is seen in the case of bougainvillaea, which will flower soon after pruning if proper fertilizer and watering are applied. Other flowers, such as roses and jasmine also require pruning to induce flowering.
2. **Pinching:** Pinching involves removing the growing tip of a shoot along with a few leaves. This is typically done when plants are young, between 7 and 15 cm in height, depending on their growth habits. Plants that require pinching include China aster, dahlia, chrysanthemum, marigold, carnation and rose.
3. **Leaf Trimming:** In some plants, like jasmine, leaves can inhibit flowering. Therefore, trimming some leaves or parts of them can help stimulate flowering.
4. **Ringing:** Ringing, which increases the carbon-to-nitrogen (C/N) ratio, can promote flowering. This technique is especially effective in fruit trees, where it encourages both flowering and fruiting.
5. **Breaking Dormancy:** The seeds and buds of some plants enter a period of dormancy where no growth occurs. Dormancy can be broken by exposure to cold temperatures or by treatment with chemicals like gibberellins. Gibberellins are particularly effective and are commonly used to break dormancy in hardy seeds and to induce flowering in various hardy plants.

Genetic interventions in regulation of flowering

- During the floral transition, shoot apical meristem (SAM) transforms from a vegetative meristem (VM) to an inflorescence meristem (IM) through sophisticated regulatory networks.

- The IM generates floral meristems (FMs), whereas VM generates leaves and side shoot meristems at its margins through a pool of self- renewing stem cells (Adrian *et al.*, 2009).
- This transition is primarily governed by genetic pathways that incorporate environmental signals like temperature, day length and the developmental state of the plant.

Drawbacks and limitation of flower regulation

- Lack of information
- Limited research on traditional flowers
- This might affect the yield, quality and fragrance of normal season bearing
- It may affect the economic lifespan of the plant
- Need for the study of plant physiology for off-season flower forcing.

Conclusion

- Offseason and specific date production
- Avoid the surplus in market during on-season
- Year-round income
- Employment
- Better utilization of land and resources
- Success depends on the skill and experience of farmers

References

Adrian J, Torti S, Turck F, 2009, From decision to commitment: the molecular memory of flowering. *Molecular Plant*, 2: 628–642.

An H R, Kim Y J, Kwon O K, Park P H, Park P M and Baek YS, 2017, High temperature promotes growth and flowering in Sophrolaelio cattleya. *Horticulture, Environment and Biotechnology*, 58: 268–273.

Anonymous (2018) AIPH—International Association of Horticultural Producers, 66th edn. Statistical Yearbook

Anumala N V and Kumar R, 2021, Floriculture sector in India: current status and export potential. *Journal of Horticultural Sciences and Biotechnology*, 96:673–680.

JUST AGRICULTURE
multidisciplinary e-Newsletter

Chandel A, Thakur M, Singh G, Dogra R, Bajad A, Soni V and Bhargava B, 2023, Flower regulation in floriculture: an agronomic concept and commercial use. *Journal of Plant Growth Regulation*, 42(4): 2136-2161.

Darras A, 2021, Overview of the dynamic role of specialty cut flowers in the international cut flower market. *Horticulturae*, 7(3):51.

El Sawy A M, Aly M M and Mohamed A A, 2021, Proftability of Lilium flowers production as influenced by light and ascorbic acid in a greenhouse. *African Journal of Agriculture and Food Science*, 4(1): 22–35

Garner J M and Armitage A M, 2008, Cooling and long-day lighting influences growth and flowering of Phlox paniculata L. "Ice Cap" used for cut flowers. Horticultural Sciences, 43: 707–709.

Greyvenstein O, Pemberton B, Starman T, Niu G and Byrne D, 2014, Effect of two-week high-temperature treatment on flower quality and abscission of Rosa L.'Belinda's Dream' and 'RADrazz'(KnockOut®) under controlled growing environments. *Horticultural Science*, 49(6): 701–705.

Hong YY, Park YJ, Kim YJ, Kim KS, 2014, Vegetative growth and flowering of Salvia splendens 'Salsa' in response to night interruption. *Korean Journal of Horticultural Sciences and Technology*, 32: 434-439.

Khan F U, Paul T M and Mir M M, 2006, Influence of low temperature on growth, flowering and vase life in tulip. *Journal of Ornamental Horticulture*, 9: 102–105.

Kim YJ, Park CJ, Rho HM and Kim K S, 2012, Night interruption and night temperature regulate flower characteristics in Cymbidium. *Korean Journal of Horticultural Sciences and Technology*, 30: 236–242.

Mattson N S and Erwin J E, 2005, The impact of photoperiod and irradiance on flowering of several herbaceous ornamentals. *Scientia Horticulture*, 104: 275–292.

Meng Q and Runkle ES, 2014, Controlling flowering of photoperiodic ornamental crops with light-emitting diode lamps: a coordinated grower trial. *Horticulture Technology*, 24: 702–711.

Monaghan J M, Wurr D C E and Fellows J R, 2004, The effects of temperature and lighting on flowering of lavender (*Lavandula angustifolia* 'Hidcote'). Journal of Horticultural Sciences and Biotechnology, 79: 811–817.

Nakano Y, Higuchi Y, Sumitomo K, Oda A, Hisamatsu T, 2015, Delay of flowering by high temperature in chrysanthemum: heat-sensitive time-of-day and heat effects on CsFTL3 and CsAFT gene expression. *Journal of Horticultural Sciences and Biotechnology*, 90: 143–149.

Nazki I T, Wani M A, Din A and Slathia D, 2018, In vitro propagation of ornamentals for maximising livelihood security. *Sustainable Agriculture Reviews*, 27: 243-270.

Noy-Porat T, Cohen D, Mathew D, Eshel A, Kamenetsky R and Flaishman M A, 2013, Turned on by heat: differential expression of FT and LFY-like genes in Narcissus tazetta during floral transition. *Journal of Experimental Botany*, 64: 3273–3284.

Oda A, Narumi T, Li T, Kando T, Higuchi Y, Sumitomo K, Fukai S and Hisamatsu T, 2012, CsFTL3, a chrysanthemum FLOWERING LOCUS T-like gene, is a key regulator of photoperiodic flowering in chrysanthemums. *Journal of Experimental Botany*, 63: 1461-1477.

Oh W, Kang KJ, Cho KJ, Shin JH, Kim KS, 2013, Temperature and long-day lighting strategy afect flowering time and crop characteristics in Cyclamen persicum. *Horticulture, Environment and Biotechnology*, 54: 484–491.

Parente E T, Carvalho G O, Pereira P C G, Torres P M, Meire R O and Dorneles P R, 2021, A review on pesticides in flower production: a push to reduce human exposure and environmental contamination. *Environmental Pollution*, 289:117817

Park YJ, Kim YJ and Kim KS, 2013, Vegetative growth and flowering of Dianthus, Zinnia and Pelargonium as affected by night interruption at different timings. Horticulture, Environment and Biotechnology, 54: 236–242.

Singh P, Tomar K S, Maurya A and Yadav A, 2023, Flower forcing: a new approach to improve farmer's income. *New Era Agriculture*, 2(4): 86-93.

Suh J K, Wu X W, Lee A K, Roh M S, 2013, Growth and flowering physiology, and developing new technologies to increase the flower numbers in the Genus Lilium. *Horticulture, Environment and Biotechnology*, 54: 373–387.

Thompson D I, Mtshali N P, Ascough G D, Erwin J E and Van Staden J, 2011, Flowering control in Watsonia: effects of corm size, temperature, photoperiod and irradiance. *Scientia Horticulture*, 129: 493–502.

Torres A P and Lopez R G, 2011, Photoperiod and temperature influence flowering responses and morphology of tecoma stans. *Horticultural Science*, 46: 416–419.

Warner RM, 2010, Temperature and photoperiod influence flowering and morphology of four Petunia spp. *Horticultural Science*, 45: 365–368.