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Innovative flower forcing methods for year-round bloom in commercial floriculture

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Abstract
Flower forcing is a vital technique in floriculture that enables the controlled induction of flowering in major flower crops outside their natural blooming seasons. This review compiles advances in environmental, chemical, and mechanical methods used for flower forcing in crops such as chrysanthemum, marigold, rose, tuberose, and jasmine. Key factors influencing flowering—temperature, photoperiod, and plant growth regulators—are discussed alongside case studies demonstrating practical applications. Methods like photoperiod adjustment, pruning, application of gibberellins, paclobutrazol, and ethylene-based treatments have been shown to significantly enhance off-season flower production, flower quality, and yield. Flower forcing not only stabilizes flower supply and market prices but also supports farmer income and employment throughout the year. The review concludes that integrating crop-specific forcing strategies can effectively address market demands while optimizing floricultural production systems.

Keywords: Flower forcing, off-season flowering, photoperiod control, plant growth regulators

Introduction
Flowering behavior in plants varies according to environmental factors such as temperature and photoperiod, as well as the plant's genetic constitution. Based on these factors, plants can be broadly classified into two groups: all-year-round flowering plants and seasonal flowering plants. In all-year-round flowering plants, some species show little or no seasonal influence and bloom consistently throughout the year, as seen in roses, marigold, chrysanthemum, and heliconia. Others in this group show great seasonal influence, with flowering peaking under favorable climatic conditions, such as in jasmine and dendrobium orchids. Seasonal flowering plants, on the other hand, bloom only during specific seasons. Their flowering is either influenced by temperature—especially low temperatures as in tulips, amaryllis, and daffodils—or by photoperiod. Photoperiod-influenced plants are further divided into short-day plants, which flower when day length is shorter than a critical value (e.g., poinsettia), and long-day plants, which flower when the day length is longer than a critical value (e.g., Siam tulip). Due to this varied flowering behavior, flowers available in their normal season are often abundant and fetch lower prices, whereas flowers are in high demand and command better prices during the off-season or on special occasions like Valentine's Day, Mother's Day, and festivals. To take advantage of this, farmers adopt flower forcing techniques, which involve inducing flowering at desired periods by manipulating factors such as photoperiod, temperature, fertilizer application, plant hormones, pruning, leaf trimming, ringing, and breaking dormancy. Flower forcing allows for the production of flowers during off-seasons and specific dates, helping growers meet market demand and achieve higher profits.

Objectives
The purposes of inducing plants to flower during the off-season or on specific dates are as follows.

- **To prevent an oversupply of in-season cut flowers:** Since most cut flowers are produced during seasons with favorable growing conditions, large quantities become available, often resulting in lower prices or unsold stock.
- **To minimize wastage or spoilage of excess cut flowers:** Unlike many other products,

cut flowers are highly perishable. If not sold or used promptly, they deteriorate and become waste.
- **To reduce the risk of pest and disease outbreaks:** Peak season cut flower production is often vulnerable to insect infestations and disease outbreaks due to favorable climatic conditions that support both plant and pest growth.
- **To ensure year-round employment opportunities:** Cut flower cultivation is labor-intensive. While there is ample employment during peak seasons, off-season flower production helps maintain consistent labor demand throughout the year, supporting the broader economy.
- **To boost farmers' earnings:** Farmers can increase their income by supplying flowers when market demand is high, especially during off-seasons.
- **To reduce flower imports and improve trade balance:** Florists often rely on imported cut flowers to meet customer demand during times when local production is insufficient. Producing flowers off-season helps reduce import dependency and contributes to a healthier trade balance.
- **To meet customer demand throughout the year:** Customer needs for cut flowers are not limited to a particular season but are spread across the year for various occasions. Off-season flower production ensures that these needs are consistently met.

Hypothesis of flowering
Plants undergo different developmental phases throughout their lifecycle. The transition occurs from the juvenile vegetative phase to the adult vegetative phase, during which plants become receptive to environmental signals for flowering, particularly temperature and day length. The organs responsible for detecting these environmental changes are usually the leaves or meristems. This stage is referred to as the "ripeness-to-respond stage." It is hypothesized that once a plant reaches this stage and is exposed to appropriate stimuli, it initiates the formation of floral primordia through the production of hypothetical substances-'vernalin' when triggered by suitable temperatures, and 'florigen' when triggered by the correct photoperiod. These floral primordia eventually develop into flowers, which bloom in due course.

Factors affecting flowering
- **Temperature:** Temperature, particularly lower temperatures, plays a key role in promoting flowering. For instance, the colored bracts beneath poinsettia flowers will not develop their characteristic red or other hues if exposed to high temperatures. Temperature is especially crucial in initiating flowering in bulbs, where floral primordia form during storage after summer harvest and before fall replanting. Bulbs such as tulips and irises can be made to flower earlier by exposing them to low temperatures ranging from 9 °C to 13 °C. However, prior treatment at higher temperatures (20 °C to 30 °C) is often necessary to trigger flower formation in certain cases.
- **Photoperiod:** Photoperiod refers to the cycle of light and dark periods within a 24-hour day. A plant's flowering response to this cycle is called 'photoperiodism.' Based on their response to day length, plants are categorized as short-day, long-day, or day-neutral. Short-day plants flower when the day length is shorter than a specific critical duration. In contrast, long-day plants flower when the day length exceeds this critical value. Day-neutral plants flower regardless of the length of the day, showing no dependency on photoperiod.

Techniques of flower forcing
1. Manipulating factors that influence flowering
- **Temperature:** For plants that require low temperatures to flower, such as certain bulbs or seeds, this condition can be created by storing plant parts in a refrigerator or freezer.
- **Photoperiod:** The length of day and night can be controlled by using artificial lighting (e.g., tungsten bulbs, fluorescent lamps) to extend daylight hours, or by placing plants in darkness to shorten day length.
  There are two primary goals in photoperiod adjustment:
- **To trigger flowering by providing the ideal photoperiod:** For long-day plants, additional light is supplied to extend day length beyond the critical limit, encouraging flowering.
- **To maintain plants in a vegetative state by preventing flowering:** For short-day plants, extending day length using artificial light keeps them from flowering. For instance, chrysanthemum requires 14.30 hours or fewer of daylight to bloom. By providing supplementary light to exceed this threshold, flowering is delayed until the desired time.

Photoperiod management in Chrysanthemum
- **Artificial Lighting (Long Days):** After planting, chrysanthemums receive artificial light to promote vegetative growth. Fluorescent, incandescent, or mercury lamps are used, with an intensity around 150 Lux. Lights are typically suspended two meters above plants, spaced four feet apart. Lighting is provided for four hours at night, from 10 p.m. to 2 a.m., effectively splitting the dark period and preventing flower bud initiation.
- **Artificial Shading (Short Days):** Once adequate vegetative growth is achieved, short days are induced to stimulate flowering. Plants are covered for 14 continuous hours daily, from 5 p.m. to 7 a.m., using black alkathene sheets. This practice continues until flower buds show color. For spray varieties, 11 to 12 hours of shading is sufficient for optimal flowering and lateral branch development.

2. Chemical flower forcing
Flowering can also be influenced by four main types of chemical applications:
- **Fertilizers:** The carbon-to-nitrogen (C/N) ratio plays a crucial role in flowering. A higher C/N ratio promotes flowering, while a lower ratio keeps the plant in a vegetative phase.
- **To delay flowering:** Apply nitrogen-rich fertilizers and ensure adequate watering for quick nutrient uptake.
- **To encourage flowering:** Use fertilizers with lower nitrogen content and reduce watering. Additionally, chemicals that bind nitrogen can help induce flowering.

Plant Hormones

- **Gibberellins (GA):** Over 50 types of gibberellins have been identified. They promote extensive plant growth and can replace long-day or cold period requirements in some species. Flowering induced by long days or cold exposure is often linked to increased endogenous gibberellin levels.
- **Ethylene:** Ethylene promotes flowering in certain plants like pineapple. It can be applied using acetylene or commercially available products such as ethephon (Ethrel). While ethylene induces flowering in crops like mango and bromeliads, it generally inhibits flowering in most other plants.
- **Growth Retardants:** These synthetic substances, including Phosphon D, Amo1618, CCC (Cycocel), and Ancymidol, limit stem elongation by suppressing gibberellin synthesis. Growth retardants like CCC help initiate floral primordia by reducing internal gibberellin levels or counteracting their inhibitory effect on flower initiation.
- **Other Chemicals:** Additional substances like potassium chlorate, sodium chlorate, potassium nitrate, thiourea, and paclobutrazol (Cultar) are used to induce flowering, especially in fruit trees. These are typically applied as soil drenches or foliar sprays.

Mechanical methods of flower forcing

- **Pruning:** Pruning adjusts the C/N ratio, encouraging flowering. For instance, bougainvillea blooms after pruning combined with proper fertilization and watering. Roses also require pruning to stimulate flower production.
- **Leaf Trimming:** In some species, such as jasmine, certain leaves can inhibit flowering. Removing a portion of the foliage can help promote flowering.
- **Low-Temperature Storage:** Flowering in many plants can be induced by storing bulbs or corms at low temperatures for a specific period before planting.
- **Breaking Dormancy:** Dormant seeds and buds can be encouraged to grow through low-temperature treatment or the application of chemicals like gibberellins. Gibberellins are particularly effective for breaking dormancy in seeds and plants that require cold exposure to flower.

Forcing of some flowers

Marigold (*Tagetes erecta*)

Marigold is a day-neutral plant that flowers throughout the year. It generally takes around 60–70 days from sowing to harvest. Flowering time can be regulated by adjusting the sowing date approximately 60–70 days ahead of the desired harvest date. Typically, sowing is planned about 65 days before the intended flowering period.

Lotus (*Nelumbo nucifera*)

Lotus flowers year-round but requires standing water. The forcing technique in lotus varies with the season. To maintain consistent blooming during winter when temperatures drop, lowering the water level to 50 cm helps increase water temperature, ensuring flower size and quantity comparable to summer. During summer, when high temperatures can accelerate growth and early flowering, raising the water level to 75 cm from the winter level helps cool the water, maintaining stable flower production and size. To handle additional rainfall, maintaining a 50 cm water level is recommended, allowing rainwater to raise the level slightly without affecting the blooming process.

Jasmine (*Jasminum sambac*)

Jasmine typically blooms from March to June, continuing until October. Flower production and quality decline from November to February. By shifting the pruning period earlier to September instead of the usual late November, flowering can be promoted during the winter lean period, increasing both yield and flower quality. This adjustment led to a 2.67 times higher yield compared to November pruning. The benefit-cost ratio also improved significantly, reaching 2.51 versus 1.66 under conventional practices, thereby enhancing farmer profitability.

Roses (*Rosa hybrida*)

Although roses bloom year-round, peak flowering is seen during cooler seasons. To produce flowers around Christmas and New Year, pruning is recommended in November, as flowering generally occurs about 43 days after cutting. For flowering timed around February 10th, cutting the flowers on December 23rd is advised, with blooms appearing approximately 49 days later. This scheduling ensures flowering aligns with specific festive periods.

Gladiolus (*Gladiolus grandiflora*)

In cooler regions, flowering in gladiolus can be encouraged by preheating the corms for two weeks at temperatures between 27 °C and 32 °C before planting. This treatment stimulates earlier flowering. In warmer regions, a different method is suggested. Corms are soaked in a gibberellic acid (GA) solution at concentrations of 10 to 25 ppm prior to planting, which speeds up flower primordia development and promotes quicker blooming.

Research outcomes

The study by Sangma *et al*. (2016) [20] evaluated the effect of different covering materials like tarpaulin, HDPE, and black satin cloth on off-season cut flower production in eight chrysanthemum cultivars. The results showed that covering materials successfully induced early flowering compared to natural photoperiod conditions. Among the treatments, HDPE proved most effective, producing plants with optimum height, controlled plant spread, the highest number of cut stems per plant, early visible flower bud formation, and longer flowering duration. While black satin cloth resulted in the tallest plants and greater plant spread due to its partial light transmission, HDPE and tarpaulin produced sturdier plants with better commercial traits. Cultivars such as Tata Century, White Star, and White Bouquet responded quickest to short-day treatment under HDPE, requiring only eight weeks to flower. The study concluded that HDPE is the most suitable covering material for off-season chrysanthemum production, offering advantages such as effective artificial short-day creation, lighter weight, ease of handling, and suitability for all tested cultivars.

The study by Sathappan (2018) [21] investigated the effects of various plant growth regulators and pinching on the growth, flowering, and yield of two African marigold hybrids: Gold Benz Tall and Maxima Yellow. The results showed that foliar application of GA_3 at 150 ppm significantly enhanced plant height, number of laterals, number of leaves, leaf area, number of flowers per plant, flower yield per plant, and xanthophyll content compared to other treatments and control. While pinching reduced plant height and delayed flowering, it also contributed to increased branching. Growth retardants like MH and Alar delayed flowering and reduced overall yield. The best performance in terms of flower yield and quality was consistently recorded in both marigold varieties treated with GA_3 at 150 ppm. The study concluded that foliar application of GA_3 at 150 ppm is the most effective method for maximizing flower yield and xanthophyll content in African marigold cultivation.

The study by Younis *et al*. (2013) [30] evaluated the effect of different winter pruning dates on the growth and flowering performance of Rosa centifolia. Five pruning dates from mid-December to mid-February were tested. The results showed that pruning at the end of December (T_2) consistently produced superior outcomes across all measured parameters. Plants pruned on this date exhibited the tallest height (141.87 cm), the highest number of branches (44.93 per plant), the greatest branch length, the maximum number of buds (25.23 per plant), and the shortest time to bud emergence (16.30 days). In terms of flowering, T_2 also resulted in the highest number of flowers per plant (556.60), the largest flower diameter (5.25 cm), and the heaviest fresh flower weight (2.13 g). Based on these findings, the study concluded that pruning Rosa centifolia at the end of December is the most effective practice for enhancing both vegetative growth and flower yield, ensuring better quality and quantity of blooms.

The study by Yang *et al*. (2014) [29] evaluated the effects of different planting dates and varieties on the growth and flowering of tuberose under winter greenhouse conditions in Tianjin, China. Two varieties, 'Single' and 'Double,' were planted on October 30th, November 30th, and December 20th to observe differences in dormancy release, flowering behaviour, and flower quality. Results showed that earlier planting, especially on October 30th, produced superior outcomes in both varieties, with 'Double' performing better than 'Single' in terms of corm sprouting rate, number of florets, spike length, and overall flower quality. October planting of 'Double' variety produced cut flowers comparable to field-grown tuberose, while later plantings resulted in reduced quality due to lower temperatures and shorter photoperiods. The study concluded that for winter forcing cultivation of tuberose, planting 'Double' variety in October is most suitable to achieve higher sprouting, better flowering characteristics, and superior quality cut flowers in greenhouse conditions.

The study by Kalaimani *et al*. (2017) [12] evaluated the effect of different pruning times and plant growth retardants on the growth and off-season flower production of *Jasminum sambac* (cv. Ramanathapuram Gundumalli). Results indicated that pruning during the last week of September, combined with foliar application of mepiquat chloride (MC) at 150 ppm, significantly improved vegetative growth parameters such as plant spread, number of primary and secondary branches, and ultimately led to the highest flower yield during the off-season (December to February). This treatment (P2T9) produced the greatest number of flower buds per cyme (7.70), highest weight of 100 flower buds (28.00 g), and maximum flower yield per plant (222.47 g) and per hectare (1423.81 kg). Early pruning helped plants benefit from longer photoperiods and higher temperatures, while mepiquat chloride redirected resources from vegetative to reproductive growth, enhancing flower production. The study concluded that combining September pruning with MC 150 ppm spray is an effective strategy to boost off-season flower yield in *Jasminum sambac*.

Conclusion

Flower forcing is a key practice in floriculture that allows growers to control flowering time, ensuring consistent flower availability throughout the year. By enabling off-season and date-specific blooming, it helps meet market demands during high-value periods, increases farmers' income, and minimizes surplus and wastage during peak seasons. Overall, flower forcing supports year-round flower production, stabilizes market supply, and enhances grower profitability and consumer satisfaction.

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