Photoperiod: A Key Pathway For Manipulation of Flowering Time In Commercial Ornamental Crops

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Abstract

Transition from vegetative stage to reproductive stage is very critical in the life of flowering plants.Initiation of flowering is regulated by various environmental (photoperiod, temperature) as well as endogenous plant factors (age of the plant, hormones, sugars etc.). Among all, photoperiodic manipulation has been used since long for regulation of flowering time in commercial cut flowers and potted plants. By understanding the role and functioning of photoperiod, flowering time can be regulated and plants can be made to flower at any time irrespective of the season. This concept is attracting immense attention in the field of ornamental crops as these crops are hugely demanded during festivals and special occasions (Valentine's Day, Mother's Day). Studies related to major pathways controlling flowering time in different crops has been done which presents ample opportunities in field of flower regulation in ornamental crops.

Key Words: Physiology, Flowering time, Photoperiod, Ornamental crops.

Ornamental plant sector is a potential money-spinning and income generating sector which can contribute towards economy generation. People are nowadays are learning the ways of modern living with inculcation of habit of surrounding themselves with beautiful ornamental plants. Throughout the world and specifically in India, flowers find place in all occasions,we need flowers for every ritual, every festival or for any kind of celebration. Flowers are also the source for visitor's attraction in specially organised flower shows, conferences and gatherings. With huge demand still there is trend to produce the flowers with traditional technologies of production during the normal season of growing which cannot fullfill the requirement of flowers. Apart from that when flowers are produced during on season, growers fetch low price due to surplus in one season and the same produce can fetch double price if produced during off season or special occasion. Therefore, regulation of flowering time which means production of flower at desired dates that can be for sold at top prices than the flowers produced during natural blooming season has become significant to the flower growers. Basically, flower regulation is an operation performed or treatment given to the plant at appropriate stage (ripeness-to-flower stage) to stimulate it to flower at a desired time (e.g. on Easter day, Diwali) or during off-season. As with increased desired for always 'new' in ornamental plant industry, growth regulation is the important way out (Andersen and Andersen, 1999).As flowering is under control of complex network of environmental and endogenous factors, proper understanding of these factors with respect to physiological and genetic bases is necessary that ultimately control the flowering time.

Physiology of Flowering:

In order to complete the reproduction cycle and survival of the species, initiation of flowering is the most imperative step in life cycle of flowering plants. Plants respond to multiple factors for this process to begin which includes the environmental factors and some endogenous factors. Different environmental cues include, temperature, photoperiod, season etc. and endogenous clues include length of the juvenility and available energy (Milec *et al.*, 2014). This elaborate process of forming of floral organs and turning to complete flower has been elucidated in *Arabidopsis thaliana*. Earlier, scientists believed the existence of floral stimulus in the plant leaves that is imperative for floral initiation. Chailakhyan named this floral stimulus as 'florigen' (Chailakhyan, 1936) and further with the contribution of many researchers in this field complete physiology, genetics (including identification regulatory proteins and key transcription factors) of flowering has been elucidated. Integration of enviormnetal factors with plants' endogenous cues along with interacting proteins forms the biochemical basis for initiation of floral identities. Though with much advancement in this field, knowledge is still meagre related to crop specific physiology, biochemistry and genetics of flower initiation as studies proved that identities of pathways defined in Arabidopsis differs in other crops(Andres and Coupland, 2012; Tsuji *et al*., 2011). Flowering is the most important attribute in ornamental plants where its onset has huge impact on its quality and marketability. So, studies specifically pertaining to elaboration of physiological, biochemical and genetical pathways in ornamental crops need to be focussed. In general, Anthesis irrespective of the crop begins with perception of Proper stimuli (temperature & photoperiod)

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at ripeness-to-flower stage with further role of vernalin (cold stimulus) or florigen that terminates to Flower development.

Genetic control of flowering time in relation to photoperiod:

Transition of plants from vegetative to flowering stage is a major physiological change which is under control of intricate network of controlling factors. These controlling factors are the plants' endogenous and exogenous cue which acts as transition signals for flowering (Song *et al*., 2013). Genetic control of flowering time is very complex and has been studied majorly in *Arabidopsis thaliana* (Milec *et al.*, 2014) and with the studies conducted on several other species it has been reported that there are specifically five genetically regulated pathways that control flowering. Advancement to flowering in response to cold temperature conditions is known as vernalization pathway (Sheldon *et al*., 2000). Initiation of flowering in response to light duration and quality of light perceived is known as photoperiod pathway (Thomas and Vince-Prue, 1996; Reeves and Coupland, 2000). In some species flowering time is under the control of hormones specifically gibberellic acid which refers to gibberellins pathway. There exists an another pathway When flowering is not influenced by gibberellins and photoperiod but initiates under the control of plants' endogenous regulators is called autonomous pathway which indicates the role of plant age as endogenous regulator of flowering time.

Photoperiod or relative day length varies according to the season as we experience shorter days in winter and longer days in summers when move away from equator. This fluctuation in day length is perceived by plants and indicates their response to flowering control. Plants perceive the light through special photoreceptors at different wavelengths; blue light by phototropins and cryptochromes, red light/far red light by phytochromes. Several explanations based upon the studies on several flowering plants has been given to indicate the mechanism by which photoreceptors perceive the light signals and mediate the flowering response (Quail et al., 1995; Lin et al., 1998). Two distinct phytochrome responses have been reported in case of chrysanthemum (Higuchi *et al*., 2012). Phytochromes require the internal cues i.e. vast network of genes which functions under circadian clock and environmental influences to perceive light at different wavelength and control flowering. CONSTANS (CO) is the key gene controlling the photoperiod mediated induction of flowering. CO is under the control of circadian clock which that leads to varied responses under short days and long days respectively (Putterill et al., 1995). Under long day conditions along with CO other proteins also plays major role viz; GIGANTEA (GI), FLAVIN-BINDING, KELCH REPEAT, F-BOX 1 (FKF1), and CYCLING DOF FACTOR1 (CDF1) (Fornara *et al*., 2009). Expression of CO is regulated by complex interaction of FKF1-GI complex with CDFs where FKF1-GI complex is formed more under presence of blue light i.e. long day conditions and it forms less under short days due to deficiency of blue light (Sawa et al., 2007). Analysis research has shown that among the three proteins, CDF1 peaks first, followed by GI, and then finally FKF1 peaks in the afternoon in long days (Fornara *et al*., 2009). Taken together, the activity of FKF1/GI/CDFs results in a second peak of CO expression towards the end of the subjective LD at approximately 16 h after dawn. Regarding the role of floral stimulus 'florigen' studies in Arabidopsis proves that florigen is realized by FLOWERING LOCUS T (FT) encoded protein (Turck *et al.*, 2008). Transport of FT from phloem companion cells to shoot apical meristem transfers the photoperiod signal to site of floral initiation (Corbesier *et al.*, 2007). Expression of CONSTANS (CO) is required for activity of FT (Tiwari *et al.*, 2010).

Photoperiodic manipulation: Plant responding to relative day length or photoperiod can be subjected to forcing by photoperiodic manipulation. Plants will sense these variations in the length of the day with their cues and signaling pathways that will ultimately manipulate their flowering behavior. This very phenomenon served as basis for flower regulation in many florists crops from earlier times.Plants can be divided in to different classes on the basis of their response to day length for flowering (reviewed by Ha *et al.*,2014)

Table 1: Classification of plants on the basis of photoperiodism.

Class	Examples	Critical day length	Flowering season
Short day plant (Long night)	Chrysanthemum, Poinsettia, Cocklebur, Morning glory, Dianthus	Daylight is less than a critical length (8 hrs light and 16 hrs dark)	Late summer, fall, or early winter
Long day plants (short night)	Iris,carnation, Henbane,	When daylight is increasing (16 hrs light	Spring and early summer

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	Arabidopsis, Zinnia	and 8 hrs dark)	
Day neutral	Rose,Balsam, Gomphrena	No response to daylight changes	At particular stage of maturity
Intermediate	Coleus, *Echinacea purpurea*	Which respond to narrow range of photoperiods	
Short-long day	Campanula	Which require short days followed sequence of long days	
Long-short day	Aloe	Which require long days followed sequence of short days	

For photoperiodic manipulation, instead of light period what matters more is the duration of dark period. Short day plant flowers when grown under short days, but if the long dark period is interrupted by flash of with light with no change indaylength, flowering will be inhibited in short day plants. So using this phenomenon, photosenstitive plants plants can be scheduled to flower at any desired time either by providing supplementary light to achieve artificial long days or by extending the dark period dark to achieve artificial short days.

Creation of short days: Short days can be created by using black plastic, polyolefinsheeting,black tarpaulin, and Black sateen cloth over a crop to block out the light. Dense black polythene sheeting (150 gauge thick) is the most suitable material for complete black outs. Light levels should be <0.5 foot candles in a blackout situation. Blacking out at either end of the day is considered to be the best. In chrysanthemum plants are covered at 5 pm and removed at 9 am.Palai *et al*. (2018) has suggested the use of black tarpaulin suspended on an iron frame from 5 PM until 7 AM for creation of short days in chrysanthemum scheduling.

Creation of long days: In order to get early flowering in case of long day plants we need to maximize the day length i.e. providing the plants with artificial long days in naturally prevailing short days or supplementing the natural long days. Supplemental lighting provided can also keep the short day plants in vegetative stage in order to prepare plants for large scale propagation. Techniques to create long days include extension of day length by providing lights in greenhouse or night break lighting i. e. breaking the long dark period in night by providing light for four hours continuously in greenhouse. Light sources used for artificial lighting are incandescent bulbs, high-pressure sodium lamps (HPS). Light-emitting diodes (LEDs) are also being used recently but are costly and depend upon number of plant factors. The desired light intensity at plant level is minimum 10 foot candles between 8am and 4pm. nowadays cyclic or intermittent lighting is more becoming more popular in commercial flower regulation programs. It is achieved by incandescent lamps kept on a timer and setting them to turn on in the middle of the darkperiod for a specific cycle (Boyle, 2017).

Techniques of photoperiodic manipulation in commercial ornamental crops:

Flower regulation in Chrysanthemum (*Dendranthema grandiflora*): Chrysanthemum is a qualitative short day plant so effectively responds to light manipulation for flower initiation**(**McMahon, 1999). However the photoperiodic response of chrysanthemum is further modified by temperature as well as cultivar and chrysanthemum possesstwo critical photoperiods, one for floral initiation and a different one for flower development. Large scale production of chrysanthemum with light control mechanism using black plastic started in 1950's which started with manual operations and later momentum begin with automated light control system(Bergstrand, 2017).Most varieties of chrysanthemum are basically autumn flowering plants i. e. they flower when daylength become shorter so popularly called "Short day plant". This characteristic of chrysanthemum can be commercially exploited for promotion or inhibition of its flowering by providing extended dark period or by night break lighting respectively.But before the beginning of short days they are kept under long day conditions for desired stem growth specifically for cut flower production (Hisamatsu *et al*., 2008). In case of chrysanthemums, Incandescent bulbs (100W) were most popularly used for "night break" earlier. But nowadays, energy saving bulbs of 23 W power are used which are energy efficient. Red light emitting LED bulbs (10W) can also be used successfully in chrysanthemum to regulate flowering. Jeong *et al.*, (2013) indicated that production of cut

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chrysanthemum can be supplemented with blue (B) spectrum lighting as it helps in elongation of stem and internode growth without any inhibitory effect on flower bud formation.

Year round flowering in chrysanthemums was first suggested by Post in 1947. Growing scheduling for year round production or even a single crop must follow certain principles in order to grow high quality flowers which were clearly underlined by Dutta and Gupta (2012) where planting followed by pinching and then induction of short days when stems reach to specific height after pinching. Short days are given until flower bud initiationto a stage no longer affected by daylength**.** After the harvesting the plant stubbles are removed and land is prepared for next planting. All the cultivars are not suitable for year round schedule as they differ in their short day requirement and belong to different response groups. So selection of responsive cultivar is prerequisite for scheduling of chrysanthemum. elaborated classification of small and large flowered chrysanthemum cultivars according to response group and their response to short day and long day treatment has been given by Datta and Gupta (2012).

Table 2: Response groups in chrysanthemum with respect to planting, pinching and flowering dates.

Response Gruop	**ApproximatePlanting date**	**Approximate Pinching date**	**Natural Flowering date**
7 week	June 25	July 9	22 September – 9 October
8 week	July 2	July 16	12 October- 21 October
9 week	July 9	July 23	22 October- 1 November
10 week	July 16	July 30	2 November- 11 November
11 week	July 23	August 6	12 November-21 November
12 week	July 30	August 13	22 November-4 December
13 week	August 6	August 20	5 December-11 December
14 week	August 13	August 27	12 December-26 December
15 week	August 20	September 3	27 December – 5 January

Rani (2010) had investigated the effect of photoperiod treatment on different chrysanthemum selections and reported that under controlled photoperiod all the selections had taken less number of days (116.53) to initiate flowering where as in case of natural photoperiod more number of days (192.15) were taken to initiate flowering.Higuchi *et al.,* (2012) studied the role of light quality during photoperiodic regulation of *Chrysanthemum morifolium* and observed thatquality supplied during the daily photoperiod affects the light quality required for effective night break.Kawata *et al*. (1987) through his studies on chrysanthemum reported that in life cycle of chrysanthemum is completed in four developmental phases viz; rosette, juvenile, photoperiod-sensitive and ripening. Cold treatment is required for completion of rosette stage, then plants need high temperature to overcome the juvenile phase which then subsequently switched to short day induction to complete the requirement of photoperiod-sensitive stage.

2. Flower regulation in Carnation: Modern carnation cultivars are quantitatively long day plants, i.e. flowering is hastened by long days. Extended lightening durations can produce significant differences for number of days taken to flowering where as short days can inhibit the flowering. But short days have been shown to promote the lateral branching where long days inhibit it. Long days are desired for stem elongation and rapid flowering in carnation (Heins and Wilkins, 1977)Earlier studies done by Freeman and Langhans (1965) showed that supplemental lighting in carnation can hasten its flowering as plants grown under long days (18-hr) were taller, flowered earlier and produced fewer nodes than plants grown under short days (9-hr). They have clearly underlined the other commercial application that for taking uniform cuttings from stock plants they should be grown under controlled photoperiod i.e should be provided with short day conditions under natural photoperiod (March- September). Later Dahab (1967) confirmed that along with photoperiod i. e long day treatment, light intensity also strongly affect the growth, bud initiation and subsequent flowering quality in carnation. As per Sparnaaij *et al.* (1990), early flowering cultivars of carnation respond better to artificial long day treatments than traditional commercial cultivars. Their studies on twenty carnation genotypes resulted in wide variations for flowering time and response to LD treatments with average flowering dates varying from 132 days to 181 days. While studying the effect of shading on carnation growth Hlatshwayo and Wahome (2010) reported that increased level of shading can decrease the number of cut flowers per plant significantly whereas reverse is true for increasing the flowers number and early flowering.

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Table 3: Effect of artificial long day flowering of carnation (Dalal *et al.*, 2006)

Photoperiod	Days for full bloom	Days for harvest
Normal	140.01	173.68
Long day	117.43	154.51
C D @5%	2.40	2.28

3. Flower regulation in *Poinsettia pulcherrima*:Based upon the response to light, Poinsettia has been classifies as short-day plants but this response is further influenced by temperature and different cultivars (Mastalerz, 1970). For flowering, poinsettias require approximately 12 hours 40 minutes as its critical day length requirement and that day length is achieved naturally around 20th September in the Northern hemisphere to initiate flowering. During natural long days to prepare poinsettia for flowering, artificial short days can be created by covering the pots with dark cloth from 17:00 hours to 8:00 hours. Further to delay flowering in the short days, plants can be provided with night break lighting from 22:00 hours and 2:00 hours(Kobayashi, 2014).The role of photoperiodic control in the flowering regulation of poinsettia was described by Parker *et al*. (1950), which ultimately led to the commercial introduction of poinsettia. Effect of light quality was also studied in poinsettia. Light emitting diodes with different light quality along with or without High pressure sodium lamps were used where they observed the improved growth habit i. e. reduced plant height, whereas flowering time was not delayed by different light quality (Thapa *et al.*, 2016).

Flower regulation in other ornamentals:

Baloch *et al.*, (2011) implicated that the flowering of long day annuals viz., pansy, snapdragon and petunia was advanced (58.20, 92.00 and 57.90) under long day conditions and delayed (71.20, 126.90 and 86.60) under short day conditions whereas in cosmos which is a qualitative short day plant, flowering was delayed (88.40) by long day conditions and advanced (66.20) under short days. Studies conducted on night interruption lighting with low light intensity and high light intensity in cymbidium cultivars shown that night interruption lighting has important role in reducing juvenile phase in cymbidium which otherwise takes 5 years to bloom. Both the treatments (Night interruption with low light and high light intensity) resulted in earlier flowering (within two years) (Kim *et al.*, 2011). In cyclamen which is a day neutral plant, supplemental lighting can result in earlier flowering and can

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improve the quality of flowers in potted cyclamen (Verberkt *et al.*, 2004). Oh *et al.*, (2009) achieved earlier flower initiation (From 133 days to 75 days) in potted cyclamen plants by a low ambient DLI which was less than 12 molm–2 d–1. In *Hydrangea microphylla* effect of irradiance and short day treatment has been studied under moderate temperature and high temperature module where it was reported that both treatments have promotive effect on flowering under moderate temperature but under high temperature only short day treatment resulted in earlier flowering Nordli *et al.*, (2011). In *Lisianthus*, effect of supplemental lighting using High pressure sodium lamps has been studied by Paradiso *et al.*, 2007. According to the studies, extending the natural light hours has been significant for flowering in cultivars studied. Earlier flowering has been recorded in plants provided with supplemental lighting.

Conclusion:

Plants response to light i.e photoperiodism in ornamental plants has been successfully demonstrated from earlier times and being supplemented with research in recent time to improve the technology. But situation is critical when it comes to application of technique by growers as it requires lots of inputs like lightening equipments, shading clothes along with technical inputs and experts. All these adds to the cost of production which is for most of the times, not compensated by outcome generated. So in order to attain desired output growers should be provided with information on scheduling calendar for different crops as per occasion and demand along with specific regulation method for each crop. Marketing facilities must be well ensured in advance along with government support.

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