Bardhan and Sharma, Vegetos 2018, 31:1
DOI: 10.4172/2229-4473.1000367

Vegetos- An International Journal of Plant Research

Research Article

A SCITECHNOL JOURNAL

Regulating Horticultural Crops by Cultural and Chemical Methods

Kirti Bardhan[1]* and Kapil Mohan Sharma[2]

Abstract

Horticulture crops possess an important place in our daily life. In consumer-driven trend, the demand for horticulture produce has risen along significantly around the year including their off period along with their quality attributes. Apart from the consumer demand, climate change is also impacting flowering and fruiting time which made it needful that the crop is produced on time. These have resulted in search of methods to tune or regulate horticulture crops; mostly their flowering and fruiting time so they can fulfill the prevailing demand and overcome changing climate impact. Although development in biotechnology and breeding aspects has permitted a huge development in crops availability and their sustainability; apart from these, there are several cultural and chemical methods to regulate crops based on plants' physiological responses to environment and chemicals. The purpose of this discussion is to review knowledge available on the regulation of flowering and fruiting by manipulation of environment or usage of chemicals.

Keywords

Chemical; Cultural; Crop regulation; Flowering; Horticulture; Manipulation; Synchronizing

Introduction

Horticultural crops became a part of our day to day life, with increasing consumption of fruits and vegetables to gardening to various crops at our farm. It became indispensable in our day to day activities and eventually, the demand for the product has increased around the year [1]. According to a projection by Indian Institute of Horticultural Research, the demand for fruits and vegetable was expected to be 540 MT in the year 2050 compared to present 243.5 MT [2]. With the rising demand, horticulture rose as one of the highly profitable avenues of agriculture, supplying enormous opportunities both in the rural as well as in urban areas. Currently, horticulture sector alone contributes around 30 % of the agricultural GDP from about 23.69 Million hectares of the area and accounts for 140 billion INR export value in India [1]. To fulfill the demand, genetic manipulation by breeding and/or biotechnology has allowed many of the crops to be harvested for a wider interval of the year with hybrid vigour impacting yield [3]. Evidently, it was seen among the crop of the same genotype, they vary in their flowering and fruiting time, mostly due to an environmental factor or any external injuries which leads to the change in hormonal levels. This has fonded the idea of manipulating environment (primarily but exclusively, photoperiod and temperature) or changing internal hormonal levels (levels of GA(s), ethylene, etc.) by application of chemicals or cultural practices and has been found effective [4]. Unlike animals, most plant development takes place in post-embryonic phase, where they show wide plasticity in developmental regulation [5]. One of the most plastic developmental phases in plant life cycle is a floral transition. Induction or delay in flowering is based on multiple cues which may act individually or in combination (Figure 1). Many of these cues are now identified and utilized; this review discusses various methods and their mechanism in regulating crops.

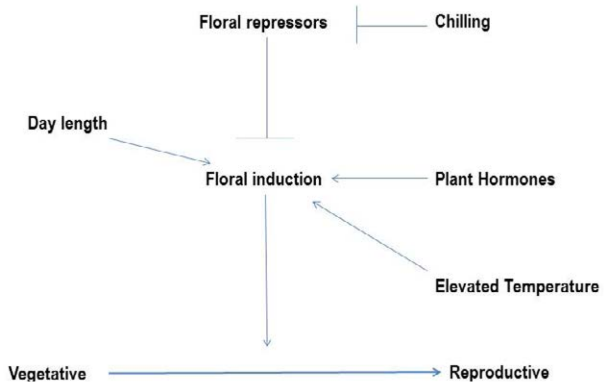

Figure 1: Factors influencing floral induction (→ Induction → stoppage).

Plant Reproductive Phase

Reproductive phase is one of the important phases in plant's life cycle. To achieve reproductive success, the plant must select the most favourable season to initiate reproductive development. This selection requires the existence of molecular mechanisms to continuously monitor environmental factors and to properly respond to the adequate conditions. Among them, light and temperature acted as most relevant to predict in terms of selection of flowering season by the plant. Although, some of the less predictable factors such as nutrient or wind can also modulate flowering time, depending on the species [6]. These environmental factors display patterns of variation in the short (i.e., diurnal variation) and long ranges (i.e., seasonal annual fluctuations). Generally, we can distinguish between plants that complete development within a year, called annual plants and plants that live more than one year, known as biennials or perennials. The first ones flower only once in their life cycle. However, among perennial plants, there are species that flower only once in their life cycle (monocarpic) or species that flowers every year, once maturity is reached (polycarpic). In annual species like *Arabidopsis*, flower initiation, defined as the morphological changes that make meristems to specify flower meristems, is immediately followed by the development of flowers. Therefore, flower initiation can be considered as a crucial regulatory point on which selection acts to ensure flowering and fruiting on time. Nonetheless, in polycarpic perennials, it is common to find a delay between flower initiation and flower development and therefore both the time of floral meristem initiation and bud burst are probably targets of selective pressure. In addition, in polycarpic and monocarpic perennial plants,

***Corresponding author:** Kirti Bardhan, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India, Tel: 02637 282 144; E-mail: kirtivardhan@nau.in

Received: October **30, 2017 Accepted:** December **07, 2017 Published:** December 11, 2017

sensitivity or responsiveness to environmental signals must change the development of the plant to prevent flowering before maturity is reached. There have been numerous recent excellent reviews on the molecular genetics aspects of flowering time control in model plant *Arabidopsis* [7-10]. The signals generated under various environment acts as cues and are discussed in the following sections.

Light

Light is the fundamental and ultimate source of all living organism and influences their activity directly or indirectly. In plants, it plays multiple roles based on its duration, spectrum, intensity or quantity. White light/ sunlight is composite of multiple wavelengths whose ratio varies from time of the day (diurnal variation) and seasonal variation and are strongly influenced by plant canopy [11]. Moreover, length of the light period (photoperiod, day-light/ dark light cycle) also shows seasonal variation. Light quality, particularly the ratio of different light wavelength (e.g. red: far red; red: blue, etc.) differentiates the growth pattern. Influence of red: far ratio acts as on/off switch for many of the growth characteristics and most important of them is flowering. In the last few decade utilization of this knowledge is widely used in the production of crops under protected cultivation to fetch good harvestable yield even in the off-season.

Photoperiod

It has been a question, how plants identify different seasons? And how they respond to it? For long it was believed to be temperature. However, photoperiod is more consistent and reliable; they follow the same pattern in same season every year, unlike temperature where seasonal fluctuation is regularly seen [12]. The sense of photoperiod length is utilized by them to identify the seasonal progression by internal circadian rhythm translating into circ-annual information.

Plants are generally classified based on their response to photoperiod as short day (SD, photoperiod longer than critical day length, e.g. strawberry, chrysanthemum, etc.), long day (LD, photoperiod than critical day length, lettuce, hibiscus, etc.) and day-neutral plants (DN, do not response any critical day length, e.g. Tomato). When we refer, photoperiod, it is actually uninterrupted dark period control plant responses to day-light. In nature, SD plants generally flower when days are short and such period is available in the winter season, whereas longer days are available in the summer season and accordingly, in wild the plant flowers when they find their suitable photoperiod. This requirement can be fulfilled in multiple artificial ways.

• **Black out for SD plants:** Since the short day plants flower when the light period is less than critical day length. This can be done by artificially creating darkness or as called as black out method or black out cloth method. The plants are grown in a structure, where darkness is created for a part of the day using dark coloured cloth. Banados and Strik [13] shows how blueberry a short day plant on providing black out treatment and permitting only 8 hours of light gives flowering whereas in natural condition 16 hours of light was present and no flowering was observed.

• **Break (LB)/Day extension (DE)/intermittent lighting for LD plants:** In contrast to the SD plants, in long day plants the day length is extended by usage of night break (usage of small duration of light in middle of night) or extending the day length with external usage of light or using cyclic intermittent lighting strategy. It is profitable approach with increased growth and quality and finally converted to revenue, like floricultural crops, *viz.* geranium, petunia, vinca, begonia, impatiens, lisianthus, and gerbera [14,15].

Light quality and quantity

Light quality signifies composition of the light. Sunlight or white light is a composite of all visible light wavelength, among which plants are sensible to group of light wavelengths with the help of specialized photoreceptors *viz.* phytochromes (Red (R) and far-red (FR) light sensing receptor) and cryptochromes (blue (B), green (G) and ultraviolet light (UV) sensing receptor) found in all organs throughout the plant life cycle and majorly detected by leaves [16,17].

In nature, the composition of the light helps the plant to identify the position of the plant among its surrounding. For example, the dominance of far-red light over red light (low R: FR ratio) make plant feel its presence in the shade. Many of the plants prefer to be in the shade (shade-loving plants, e.g. cocoa, carambola, cherries etc. and are naturally found in the forest, while the other prefers to in direct sunlight (sun-loving plant, e.g. tomatoes, cucumber, etc.). For the sun-loving plant, the presence of higher FR light reduces the flowering capacity (e.g. *Aloe vera*) whereas shade loving plant produces higher flowering (e.g. carambola) and it's vice versa. Similarly ratio of B: R, B: G and other also influence the growth and development pattern among the crops. In horticultural crops it has been generally postulated that presence long-term exposure to FR initiates events that result in higher carbohydrate accumulation in the stem than to leaves and roots compared that of R light received a plant, affecting fruit properties [18,19]. However, exposure to low light condition to indoor house plants favours flowering, inversely, longer exposure to low light or high light condition for longer duration reduces flowering proportion [20]. This information has characterized another method of crop cultivation, solely based on light-based farming.

• **Light reflectance:** Interception through the tree canopy, light penetrates and/or scatters within the tree canopy based on the structure and optical properties of the canopy components like leaves, fruits and branches [21,22]. This scattering into different wavelength results in the receptivity of ratio of their presence like R: FR ratio, B: R ratio, etc. and gives varies responses by the photoreceptors as discussed earlier. Apart from the natural means, it can be done by artificial means by manipulating the light quality. Most commonly used methods are either to use reflective films or use photo selective shade nets. Among reflective films, ground cover materials such as white woven plastics and aluminum foil serve best and help to improve fruit colour, fruit size and return bloom in crops like apple, peach and sweet cherry [23-25]. The principle behind the usage of the reflective cover is that it increases the PAR reflection by reflecting incoming light to the floor which in increases the light availability to the shading parts, helps to overcome the light deficiency in protected plants by hails nets or shade nets [25].

• **Light-based farming:** As discussed in the earlier section, photoperiodism is the response of day-night duration; however, it is also influenced by the light quality. Presence of higher far-red light shows the presence of shade or dark condition and reverse is true for red light. When crops are cultivated solely based on artificial light, utilization of specific light for the specific duration of time helps to regulate flowering and fruiting of the crop. Strawberry [26] is one the best example where early flowering was harvested just by manipulating light quality and quantity.

• **Photo selective shade net:** Similar to light based farming, photo

doi:10.4172/2229-4473.1000367

selective shade nets changes optical properties, particularly that of B: R and R: FR ratio [27]. In contrast to the light based farming, here no additional light is used and spectra are modified based on scattering and refraction of different light wavelength in different shade net. For instance, red net increases light transmission in R and FR spectra (600 – 800 nm), whereas, blue net enhanced the proportion of B light (600-700 nm) [28-31]. Shahak [32] and Nissim-Levi et al. [33] has well documented the utilization of photoselective nets for improving the performance of ornamentals and vegetables with respect to productivity, quality and harvest time in Israel. Sun-loving plants respond better when grown under red shade net, where black shade net is better for shade-loving plants.

Although utilization of light based farming technology is still limited to some countries, there is the huge scope of exploring more avenues in this method that can be the foundation of future farming systems.

Temperature

Although photoperiod is acting as a major predictable environmental factor, temperature also plays an important role in the plants' development. Similar to light, temperature also shows diurnal and seasonal variation along the day which regulates the developmental transitions such as germination, bud dormancy, and bursting, or flower initiation [34]. Both high temperature and chilling temperature play role in deciding the fate of flowering time of the crop. In many of the temperate crop, flowering is triggered by getting certain chilling hours [34] and ensures spring flowering called vernalization. Hot dry winds in the summer are not congenial for the growth and development of the flower or fruit and generally results in their shedding. Although extreme levels of both high and low temperature are not congenial, mostly during reproductive phase as that may result affect pollen viability, fertilization or fruit formation [35,36]. The crops adapted to such extreme conditions generally tune themselves by either remaining dormant or avoiding flowering during the similar period.

Chilling requirements

A large group of crops is grown in temperate conditions or low temperature. In wild, crops based on their natural habitat, they flower on the onset of spring, skipping the low temperature and frost in the winter. Individually, these crops respond to certain chilling requirement (total time spent below certain temperature; varies crop to crop) and overcoming that, the crops come into bearing. This chilling requirement is called vernalization. The plant remembers the responses of the last season and utilizes that to respond the following year. On exposure to similar lower temperature for a period of time in next year, plant reinitiates to be dormancy mostly by shading its leaves and reducing their energy consumption in different biochemical responses. This helps the plants to skip the prevailing cold weather. Based on these following methods are adapted to grow temperate crops even in the area where their minimum chilling requirement was not met.

• **Temperate crops in the tropics:** This idea has been utilized to grow the temperate crops in the tropical region by exposing the crops only once to temperate climate and then growing them in tropical zone or alternatively abscising leaves by either manual leaf pruning or chemical leaf pruning by using foliar application of urea @ 10 % or ethrel @ 3000 ppm in apple [37]. This has allowed the crops to expand its area from temperate to tropical as in the case of apple.

• **Reducing chilling requirement:** Although chilling requirements in a few crops like cherry are as high as 1500 hours and to substitute that alternative chemical approach is adopted. Cytokinin (thiodiazuron) has been found to be effective in reducing dormancy by substituting chilling requirement [38,39]. A few experiments in *Rapphanus sativus* also found induction of flowering on external GA application for the plants not exposed to chilling temperature [40]. However, Koshioka [41], suggested, GA can reduce chilling requirement but cannot substitute it in *Lavendula x intermedia* and is depended on the chilling requirement.

Elevated temperature

Unlike lower temperature, higher temperature to 27^{o} C promote flowering in tropical crops like litchi or petunia [15,42] reducing it from as high as 90 days at 14^{o}C to 30 days at 27^{0}C. Earlier, it has been a problem to grow tropical vegetable in temperate zones or vice versa. This has been overcome by usage of protected cultivated which has been advanced itself all these years where modification of light, temperature, mineral nutrients, atmospheric composition, and moisture has been possible [43,44]. Most importantly, the best favourable growing temperature can be achieved in this and its advantage has been taken to grow cole crops [45], capsicum [46], tomato [47], cucumber [48], etc. almost round the year from cold temperate zone to hot arid zones.

Hormonal regulation

Growth and development phases in plants are mostly governed by hormones and their levels. The levels of these hormones are mostly regulated by the environmental cues or some external stresses. With the advancement of time, the usage of different hormones in crop regulation has benefitted a huge number of growers. Usage of growth regulators in crop regulation is discussed as under.

Usage of gibberellin: As mentioned earlier, gibberellin plays both in making plant dormant and overcoming them. Their role in substitution of chilling requirement has also been discussed earlier. Apart from that, it has been found effective in inducing flowering in *Philodendron* [49], *Phalaenopsis* [50], *Brassocattleya* and *Cattleya* [51]. However, they have also observed that application of GA at a higher concentration or at more intervals reduces the number of flowering or delay it [50]. For dioecious crops like spinach and papaya, GA_3 has been found to induce maleness [52,53].

Usage of paclobutrazol: In some of the tropical crops increment of gibberellins had shown a reduction in the flowering number or delayed flowering and in cultivars of mango even result in the alternate bearing. The increment in the level of gibberellins represents its phase of vegetative growth period by suppressing reproductive growth. To overcome that reduction in synthesis of gibberellins is one of the adopted approaches by utilization of paclobutrazol (PBZ) or uniconazole. Davenport [54] in his experiment has shown flowering in mango can be hastened by more than one month on the usage of paclobutrazol (Table 1). Similarly, it has been found effective in regulating in acid lime [55].

Usage of ethrel: In few of the crops, flowering time of different plant varies and the grower often encounters a problem in harvesting. To stimulate synchronizing flowering, usage of ethrel has been found effective method in pineapple [56]. Apart from synchronizing it also regulate the type of flower as in case of pomegranate where more hermaphrodite flowers were produced than male flowers [57]; similarly, in papaya higher femaleness and hermaphroditism is observed on application of ethrel [58]

doi:10.4172/2229-4473.1000367

With application of paclobutrazol												
Months from synchronizing pruning for 'Haden'												
0	1	2	3	4	5	6	7	8	9	10	11	12
SP	P			NO_3^-	Flowering				Harvest			
Months from synchronizing pruning for 'Tommy Atkins'												
0	1	2	3	4	5	6	7	8	9	10	11	12
SP	P				NO_3^-	Flowering				Harvest		
Without application of paclobutrazol												
Months from synchronizing pruning for 'Haden'												
0	1	2	3	4	5	6	7	8	9	10	11	12
SP				NO_3^-	Flowering						Harvest	
Months from synchronizing pruning for 'Tommy Atkins'												
0	1	2	3	4	5	6	7	8	9	10	11	12
SP						NO_3^-	Flowering				Harvest	

Table 1: Mango flowering program with and without the use of paclobutrazol or uniconazole for early floral stimulation of an early induced cultivar (Haden) and a more difficult-to-induce cultivar (Tommy Atkins). Schedule assumes rapid flush response one month after the synchronizing pruning [54].

Usage of cytokinin: Cytokinin has been known to promote axillary branching in plants [59], their role is not extensively retained to that and has been found to regulate flowering too. BA, a commonly used cytokinin has been found to promote out of season flowering in crops like apple and portea [60,61] and also promoted bud break during late dormancy [62]. It has also promoted flowering in many herbaceous species [63] and perennial crops [64]

Stress Regulation

Apart from the normal physiological process of light and temperature, it always raised confusion, what else induced flowering, even though their natural cues were not proper and the plants are generally are in unsuitable condition. Takeno [65] have reviewed that additional responses for flowering were due to exposure to stresses. Stress is defined as any factor that interrupts or restricts the normal metabolism of the plant, and such stress can be both natural and induced. Although every year horticultural crops worth billions of rupees were lost due to damage by pests, diseases or natural calamities like drought, flood, frost or wind storms; there has been identified mechanism by which induced stress is utilized in the regulation of crops [66]. Hardening-off, controlled exposure to illumination, light wounding, and controlled temperature are some of the examples to induce or regulate or induce fruiting in several crops. Stress-induced flowering is a response to stress or stress adaptation where they tried to save their species by producing seed even when they are unable to survive themselves as an individual [65]. Even though,, these are now well-documented methods, over usage of such methods beyond the adequate level of stress are found to be detrimental or lethal [67]. The following are a few methods that are now used by inducing stresses.

Drought stress

In general, plants need water at some critical points, for most, the critical time of irrigation is when the flower or fruits are set. It was observed that, if plant passes through moderate plant deficit, enhancement in the flowering of many horticultural and forestry species like litchi [68], mango[69], Pyrus [70], etc are observed. However, if rainfall occurs before flower bud differentiation after a dry spell, it increases chances of vegetative flushes instead of reproductive flushes in mango [71]. Pongsomboom et al. [72] also showed a negative correlation in maximum flowers and relative water content in mango. Water deficit irrigation is created either by regulated deficit irrigation (RDI), where evapotranspiration (ET) is replaced by irrigation applied to entire root zone; or by partial rootzone drying (PRD) where a part of roots are irrigated leaving other side dry at a predetermined level, before being irrigated next. Such stress has influenced early flowering, however, at higher water deficit, photosynthetic activity and nutrient uptake of the plant are highly reduced resulting in greater loss resulting in wilting, abscission of parts and ultimately death of the plant and thus needs to be taken care [66].

Mechanical stress

The earliest example of mechanical stress was observed back to Roman days where girdling, cinturing, nicking, and notching were done. This is mainly an optimum mechanical damage to a plant part, which interrupts vascular cambium layer activities, mainly activities of phloem. This creates an accumulation of carbohydrates increases C: N ratio, details are discussed in next section of carbon: nitrogen ratio; it also interrupts movement of hormones and thus their ratio, promoting or interrupting reproductive phase, discussed in the last section of the hormonal regulation.

Carbon:Nitrogen Ratio

In any of the plants, the growth pattern and development phases depend on their source and sink ratio, which directly or indirectly influences their carbohydrate to nitrogen ratio. Fruit trees might be viewed as a system of sinks and sources interconnected via vascular organs (trunk, branches or scaffold roots). When the requisite amount of C: N ratio is set, it phases from vegetative to reproductive phase provided other growth parameters are satisfied. In context to that, plants naturally regulate C: N ratio by degenerating old leaves, discarding old branches, etc. It also shows higher accumulation of C: N ratio when it is followed by a wound at the cambium layer, e.g. attack of bark eating caterpillar (*Inderbela quadrinotata* Moore) or by rats, which peels the cambium layer and causes accumulation of carbon and increase C: N ratio and eventually promotes earlier flowering. Following nature, a number of practices were now adopted where C: N ratio is enhanced by simpler techniques, most common of them is pruning.

Pruning and similar activities

Another method is pruning (removal of plant parts). Pruned trees restore the root to shoot ratio. Young trees are usually pruned in order to obtain a framework that is strong and accessible for other cultural practices. Fully grown fruit trees are pruned to maintain the canopy height, spread and density required for easy spraying, fruit thinning and harvest. Time of pruning and intensity regulates the flowering time of the crop as in guava [73].

Root pruning is a horticultural practice that when coupled with other techniques will severely dwarf trees. A number of authors have suggested that root pruning induces flower initiation in apple trees [74,75]. Schumacher et al. [75,76] have reported an increase in flower number on root pruned apple trees and fruit set was reduced with decreased fruit size. A reduction in fruit size and weight was also reported for root-prune grapefruit trees [77,78]. The effect of root pruning on flowering of fruit trees is similar to the effects created by scoring or ringing the trunk.

Another method is cincturing, a ring is made around the main stem and similar to girdling, it has been effective in maintaining C: N ratio and advocates higher number of fruits in avocado [33] and litchi [79]. Although the response is based on the time of cincturing [78].

Although pruning, nicking, notching, cincturing, etc. are some of the methods where the movement of phloem is hampered and results in accumulation of carbon. These results in a reduction of the sink and thus the same amount of source will be available for a smaller group of the sink and thus level of carbon will rise and thus chances of reproductive phase. This has been found effective in many fruits crops that include mango, litchi, sapota etc.

Girdling and related techniques

Farmers have practiced the use of girdling and related techniques (Cincturing, nicking, notching ringing, scoring, strangulation, stripping and wiring) in horticulture for thousands of years in order to increase crop production. Girdling on the tree is basically an intervention in the phloem transport system between plant canopy and their roots, in an attempt to manipulate the distribution of photosynthetic, mineral nutrients, and plant hormones. However, its extensive use is limited due to difficulties in determining the optimal time and environmental conditions for each location, species and cultivar and concern on ill effect of girdling causing severe or even lethal damage by their single or repeated treatments. In spite of these reservations, girdling is widely used even today with grapes [80], citrus [81], apple [82], mango [83], Jamun [84] and other fruit crops, mainly in order to regulate growth, improve fruit set, size and quality. Among fruit trees, it has been most frequently used with mango, to demonstrate the role of leaves in supplying the floral stimulus [85]; apple [86,87] inducing flowering (up to +534 % in "Red Fuji") and in citrus [88] to hasten flowering of juvenile seedling. The promotion of flowering by girdling may reflect the need for threshold levels of carbohydrate in the canopy for flower formation [89] besides transport of plant hormones [90]. Thus girdling seems to remain an effective tool for growth regulation in both herbaceous and perennial plants, providing a positive effect on floral induction.

Twisting and bending twisting

Bending and spreading to produce dwarfed plants and various forms of topiary work are also ancient practices. Bending and tying or weighing down branch ends with a brick, planting trees at a 45^0 angle, bending and twisting branches into a loose knot have all been used in stress induction of growth of otherwise dormant lateral buds and to promote flower-bud formation and fruiting. Significant differences were seen when bending is followed in guava to produce off-season flowering [91,92] and in rose [93].

Bahar treatment

It has been a method to regulate flowering in guava [94], acid lime [95] and pomegranate [96,97], where only season of flowering is

Plant response	Natural Phenomenon	Artificial Manipulation
Photoperiod	Flowers in long day	Increasing day length by use of artificial lights (Red light)
		Night Break
		Intermittent light
		End of the day treatment
	Flowers in short day	Black out
		Reducing day length by usage of artificial lights (far-red light)
Light quantity	Low presence of light	Reflective film
		Intermittent light
Light quality	Response of different light spectra	Use of photoselective shade net
		Use of specialized lights
Temperature	Chilling requirement	Vernalization
		Use of gibberellins
Carbohydrate to nitrogen ratio	High C: N ratio favour flowering	Girdling, cinturing, Nicking and Notching
		Pruning
		Time of fertilizer application
Stress	Water stress	Withhold irrigation
	Wound injury	Girdling, cinturing, nicking and
		notching
		Shoot and root pruning
Hormonal Regulation	High gibberellins delay flowering or may favour alternate bearing	Application of Paclobutrzol or
		Uniconazol Application of ethylene
		Application of cytokinin

Table 2: Modes of artificial manipulation in horticultural crop production cycle.

selected instead of making it flower round the year. Generally, guava, citrus and pomegranate flowers thrice a year in various part of the country, *viz.* mrig bahar (flowering in rainy season, July-August); haste bahar (flowering in autumn season, October- November) and ambe bahar (flowering in spring season, February-March). Here the crop is not permitted to flower in other seasons either by manual removal of flowers or chemical thinning with ethrel, followed by giving water stress for few days' advance of required season. This method, reduces the carbon load during other seasons and thus C: N remains maintained. When the crop is needed to flower, they give higher number of flowers and comparatively better fruiting.

Discussion and Conclusion

With changing scenario, it has been important to grow the crop out of their regular season. Table 2 represents multiple modes of artificial methods by which we have succeeded in manipulating the crop production scenario along this year and continuously improving apart from breeding and biotechnological intervention. All of these methods have their own advantages and limitation. If the method of manipulation is not followed satisfactorily, consequences may result in loss of the crop; although majority of these methods were widely accepted among the growers and benefits have extracted from them.

References

1. Anonymous (2014) Handbook of horticulture statistics-2014. Department of agriculture and cooperation, Ministry of Agriculture, Government of India: New Delhi.

2. Prabhakar M, Gajanana TM, Aswath C, Krishna Reddy M, Ganeshmurthy AN, et al. (2014) Vision 2050. Indian Institute of Horticultural Research: Bengaluru.

3. Ni Z, Kim ED, Ha M, Lackey E, Liu J, et al. (2009) Altered circadian rhythms regulate growth vigour in hybrids and allopolyploids. Nature 457: 327-333.

doi:10.4172/2229-4473.1000367

4. Halevy AH (1990) Recent advances in control of flowering in horticultural crops. Adv Hort Sci 1: 39-43.
5. Scheres B, Putten WH (2017) The plant perceptron connects environment to development. Nature 543: 337-345.
6. Ausin I, Alonso-Blanco C, Zapater M, Miguel J (2005) Environmental regulation of flowering. Int J Dev Biol 49: 689-705.
7. Mouradov A, Cremer F, Coupland G (2002) Control of flowering time: Interacting pathways as a basis for diversity. Plant Cell 14: S111-130.
8. Simpson GG, Dean C (2002) Arabidopsis, the rosetta stone of flowering time? Science 296: 285-289.
9. Putterill J, Laurie R, Macknight R (2004) It's time to flower: The genetic control of flowering time. Bioessays 26: 363-373.
10. Boss PK, Bastow RM, Mylne JS, Dean C (2004) Multiple pathways in the decision to flower: enabling, promoting and resetting. Plant Cell 16: S18-31.
11. Ballare CL (1999) Keeping up with the neighbours: phytochrome sensing and other signaling mechanisms. Trends Plant Sci 4: 97-102.
12. Thomas B, Vince-Prue D (1996) Photoperiodism in plants. Academic Press, USA.
13. Banados MP, Strik B (2006) Manipulation of the annual growth cycle of blueberry using photoperiod. Acta Hort 715: 65-71.
14. Blanchard MG, Runkle ES (2010) Intermittent light from a rotating high pressure sodium lamp promotes flowering of long day plants. HortScience 45: 236-241.
15. Warner RM (2010) Temperature and photoperiod influence flowering and morphology of four petunia spp. HortScience 45: 365-368.
16. Ahmed M, Cadhmore AR (1993) HY4 gene of A thaliana encodes a protein with characteristics of a blue-light photoreceptor. Nature 366:162-166.
17. Sharrock RA, Clack T (2002) Patterns of expression and normalized levels of the five arabadopsis phytochromes. Plant Physiol 130: 442-456.
18. Kasperbahuer MJ (2000) Phytochrome in crop production. Plant-Environment interactions. Marcel Dekker, New York, USA.
19. Glenn DM, Puterka GJ (2007) The use of plastic films and sprayable reflective particle films to increase light penetration in apple canopies and improved apple color and weight. HortScience 42: 91-96.
20. Okazawa T, Nishijima T (2017) Effect of low light intensity on longevity of flowering on bedding plants targeted for indoor use. Japan Agri Res Quar 51: 279-286.
21. Palmar JW (1977) Light transmittance by apple leaves and canopies. J Applied Eco 14: 505-513.
22. Baldini E, Facini O, Nerozzi F, Rossi F, Rotondi A (1997) Leaf characteristics and optical properties of different woody species. Trees 12: 73-81.
23. Ju A, Duan Y, Ju Z (1999) Effects of covering the orchard floor with reflecting films on pigment accumulation and fruit coloration in 'Fuji' apples. Sci Hort 82: 47-56.
24. Layne D (2001) Tree fruit reflective film improves red skin coloration and advances maturity in peach. Hort Technology 11: 234-242.
25. Blanke M (2011) Managing open field production of perennial horticultural crops with technological innovations. Acta Hort 916: 121-128.
26. Stutte GW (2009) Light-emitting diodes for manipulating the phytochrome apparatus. Hort Science 44: 231-234.
27. Shahak Y, Gussakovsky E, Cohen Y, Lurie S, Stern R, et al. (2004) Color Nets: A new approach for light manipulation in fruit trees. Acta Hortic 636: 609-616.
28. Oren-Shamir M, Gussakovsky E, Shpiegel E, Nissim-Levi A, Ratner K, et al. (2001) Coloured shade nets can improve the yield and quality of gren decorative branches of *Pittosporum variegatum*. J Hort Sci Biotech 76: 353-361.
29. Solomakhim A, Blanke M (2008) Coloured hailnets alter light transmission, spctra and phytochrome as well as vegetative growth, leaf chlorophyll and photosynthesis and reduce flower induction of apple. Plant Growth Regul 56: 211-218.
30. Bastias RM, Losciale P, Chieco C, Rossi F, Corelli-Grappadelli L (2011) Physiological aspects affected by photoselective nets in apples: Preliminary studies. Acta Hortic 907: 217-220.
31. Lobos G, Retamales JB, Hancock J, Flore JA, Cobo N, et al. (2012) Spectral irradiance, gas exchange characteristics and leaf traits of Vaccinium corymbosum L. 'Elliot' grown under photoselective nets. Environ Exp Botany 75: 142-149.
32. Shahak Y, Ratner K, Giller Y, Zur N, Or E, et al. (2006) Improving solar energy utilization, productivity and fruit quality in orchards and vineyards by photoselective netting. Acta Hort 772: 65-72.
33. Nissim-Levi A, Farkash L, Hamburger D, Ovadia R, Forrer I, et al. (2008) Light-scattering shade net increases branching and flowering in ornamental pot plants. J of Hort Sci Biotech 83: 9-14.
34. Henderson IR, Shindo C, Dean C (2003) The need for the winter in the switch to flowering. Ann Rev Genet 37: 371-392.
35. Hatfield JL, Boote KJ, Fay P, Hahn L, Izaurralde RC, et al. (2008) Agriculture In: The effect of climate change on agriculture, land resources, water resources and biodiversity in the United States.
36. Hartfield JL, Boote, KJ, Kimball BA, Ziska LH, Izaurralde RC, et al. (2011) Climate impacts on agriculture: implications for crop production. Agron J 103: 351-370.
37. Efendi D (2014) Temperate zone fruits production in indonesia. Acta Hort 1059: 177-184.
38. Steffens GL, Stutte GW (1989) Thidiazuron substitution for chilling requirement in three apple cultivars. J. Plant Growth Regul 8: 301-307.
39. Faust M, Erez A, Rowland LJ, Wang SY, Norman HA (1997) Bud dormancy in perennial fruit trees: physiological basis of dormancy induction, maintenance and release. Hort Science 32: 623-629.
40. Nishijima T, Koshioka M, Yamazaki H, Mander LN (1997) Gibberellin metabolism in intact plants of Raphanus sativus. Biosci Biotech Biochem 61: 1763-1765.
41. Koshioka M, Horimoto T, Muramatsu Y, Kubota S, Hisamatsu T (2016) Florigenic effect of gibberellin on flowering according to period of chilling treatment in lavandula x intermedia. Hort J 85: 169-176.
42. Kumar SV, Lucyshyn D, Jarger KE, Alos E, Alvey E, et al. (2012) Transcrption factor PIF4 controls the thermosensory activation of flowering. Nature 484: 242-245.
43. Wittwer SH, Castilla N (1995) Protected cultivation of horticultural crops worldwide. Hort Technology 5: 6-23.
44. Santosh DT, Tiwari KN, Singh VK, Reddy ARG (2017) Microclimate control in greenhouse. Int J Curr Microbiol App Sci 6: 1730-1742.
45. Agarwal N, Mehta N, Sharma, HG, Dixit A, Dubey P (2003) Cultivation of cole crops under protected environment. Karnataka J Agril Sci 16: 332-334.
46. Rao KVR, Agarwal V, Chourasia L, Keshri R, Patel GP (2013) Performance evaluation of capsicum crop in open field and under covered cultivation. Int J Agri Sci 9: 602-604.
47. Harel D, Fadida H, Slepoy A, Gantz S, Shilo K (2014) The effect of mean daily temperature and relative humidity on pollen, fruit set and yield of tomato grown in commercial protected cultivation. Agronomy 4: 167-177.
48. Kumar S, Varsha C, Saravaiya SN, Raj D (2017) Potentiality of greenhouse cucumber cultivars for economic and nutritional realization. Int J Farm Sci 7: 1-7.
49. Chen J, Henny RJ, McConnell DB, Caldwell RD (2003) Gibberellic acid affects growth and flowering of philodendron' balck cardinal'. Plant Growth Regul 41: 1-6.
50. Cardoso JC, Ono EO, Rodrigues JD (2012) Gibberellic acid (GA3) on flowering induction and quality of Phalaenopsis orchid. Ornamental Hort 18: 135-140.
51. Cardoso JC, Ono EO, Rodrigues JD (2010) Gibberellic acid and water regime in the flowering induction of Brassocattleya and Cattleya hybrid orchids. Hortic Bras 28: 395-398.
52. Chilakhyan MK, Khryanin VN (1978) Effect of growth regulators and ole of roots in sex expressions in spinach. Planta 142: 207-210.

doi:10.4172/2229-4473.1000367

53. Han J, Murray JE (2014) The effects of gibberellic acid on sex expressions and secondary sexual characteristics in papaya. HortScience 49: 378-383.

54. Davenport TL (2003) Management of flowering in three tropical and subtropical fruit tree species. HortScience 38: 1331-1335.

55. Tripathi KM, Dhakal DD (2005) Effect of paclobutrazol on off-season flower induction in acid-lime (Citrus aurantifolia, Swingle) land races under chitwan condition. J Inst Agric Anim Sci 26: 87-92.

56. Lopez De Velez AM, Cunha GAP (1983) Da inflencia do pH e da urela na acao do acido 2-cloroetilfosfonico na inducao floral do abacaxi. Pesquisa Agropecuaria Brasileira 18: 1199-1205.

57. Azire GZ, Desai UT, Choudhari SM, Masalkar SD (1993) Crop regulation in pomegranate: I Effect of growth regulators on flower induction, sex expression and flower drop. Ann Arid Zone 32: 97-98.

58. Kumar A, Jaiswal VS (1984) Sex reversal and fruit formation on male plants carica papaya l. by ethrel and chlorflurenol. Proc. Indian Acad Sci 93: 635-641.

59. Shimizu-Sato S, Tanaka M, Mori H (2009) Auxin-cytokinin interactions in the control of shoot branching. Plant Mole Bio 69: 429-435.

60. Hoffman EW, Bellstedt DU, Jacobs G (2009) Exogenous cytokinin induces "out of season" flowering in Protea cv. Carnival J Amer Soc Hort Sci 134: 308-313.

61. Tromp J, Ovaa JC (1990) Seasonal changes in the cytokinin composition of xylem sap in apple. J Plant Physiol 136: 606-610.

62. Jones OP (1973) Effects of cytokinins in xylem sap from apple trees on apple shoot growth. J Hort Sci 48: 181-188.

63. Bernier G, Corbesier L, Perilleux C, Havelange A, Lejeune P (1998) Physiological analysis of the floral transition. Genetic and environmental manipulation of horticultural crops. CAB International, Wallingford, UK.

64. Davenport TL (2000) Processes influencing floral initiation and bloom: the role of phytohormones in a conceptual flowering model. HortTechnology 10: 733-739.

65. Takeno K (2016) Stress-induced flowering: The third category of flowering response. J Exp Botany 67: 4925-4934.

66. Grierson W, Soule J, Kawada K (1982) Beneficial aspects of physiological stress (in) Janick J. Horticultural Reviews, John Wiley and Sons, Inc, Hoboken, NJ, USA.

67. Kazam K, Lyons R (2016) The link between flowering time and stress tolerance. J Exp Botany 67: 47-60.

68. Stern RA, Adato I, Goren M, Eisenstein D, Gazit (1993) Effect of autumnal water stress on litchi flowering, and yield in israel. Sci Hort 12: 321-326.

69. Santos MRD, Donato SLR, Faria LN, Coelho EF, Junior PRFC (2016) Irrigation strategies with water deficit in 'Tommy Atkins' mango tree. Eng Agric 36: 1096-1109.

70. Mitchell PD, Chalmers DJ, Jerie PH, Burge G (1986) The use of initial withholding of irrigation and tree spacing to enhance the effect of regulated deficit irrigation on pear trees. J Amer Soc Hort Sci 111: 858-861.

71. Davenport TV (2007) Reproductive physiology of mango. Braz J Plant Physiol 19: 363-376.

72. Pongsomboom W, Whiley AW, Subhadrabandhu S (1992) Effect of air temperatures on diurnal variation of water potential, conductance and CO2 assimilation of mango (*Mangifera indica*) leaves. Acta Hort 1075: 65-74.

73. Lopez JGV, Manica I, Koller OC, Ribold IJ (1982) Effect of six pruning periods on the yield of guava in Novo Hamburgo, Rio G Randedeo, Brazil. Proc Trop Reg Am Soc Hort Sci 25: 259-262.

74. Turkey HB (1964) Effects of shoot-bending and pruning or growth and fruit bud formation in young apple trees. Hort Res 9: 93-102.

75. Schumacher R, Fankhauser F, Stadler W (1978) Beeinflussung der Fruchtbarkeit und der Fruchtqualitat durch den Wurzelschnitt. Schweiz Zeitschr Fur Obst-und Weinbau 114: 56-61.

76. Schumacher R (1975) Einfluss des Wurzelschnittes auf Fruchtbarkeit von Apfelbaumen Schweiz. Zeitschr. Fur Obst-und Weinbau 111: 115-116.

77. Chundawat BS, Randhawa GS (1972) Effect of ringing and root pruning on fruit set, fruit drop and quality of foster and Duncan cultivars of grapefruit (*Citrus paradise* Macf.) Haryana J Hort Sci 2: 6-13.

78. Hackney CR, Boshoff M, Slabbert MJ (1995) Increasing yield of young hass avocado trees using the cincturing technique. South African Avocado Growers' Association Yearbook 18: 54-55.

79. Kumar A, Pandey SD, Patel RK, Singh SK, Srivastava K, et al. (2015) Induction of flowering by use of chemicals and cincturing in 'Shahi' litchi. Ecoscan 7: 493-496.

80. Wolf EEH, Merwe GG, Orth CHF (1991) Optimal gibberellic acid concentrations for the production of high quality 'sulatania' in the ange river area. Deceidous Fruit Grower 41: 337-340.

81. Koller OL, Soprano E, Costa ACZ, Koller OC, Yamanishi OK (2000) Inducao de floracao e producao de frutos em laranjeira 'Shamouti'. Laranja 21: 307-325.

82. Arakawa O, Kanno K, Kanetsuka A, Shiozaki Y (1997) Effects of girdling and bark inversion on tree growth and fruit quality of apple. Acta Hortic 451: 579-586.

83. Jose A (1997) Effect of girdling treatments on flowering and production of mango trees cv. Tommy Atkins. Acta Hortic 455: 132-134.

84. Haldankar PM, Dalvi NV, Parulekar YR, Lawande KE (2014). Induction of flowering by girdling in jamun cv. Konkan Bahadoli. J Plant Studies 3: 45-49.

85. Davenport TL, Nunez-Elisea R (1997) Reproductive physiology. The mango: botany, production and uses. Wallingford: CAB International: 69-146.

86. Meilan R (1997) Floral induction in woody angiosperms. New Forests 14: 179-202.

87. Li TH, Hand WD, Meng ZQ (1996) Study on the mechanisms of lower bud induction in apple tree. Acta Phytophysiol 22: 251-257.

88. Furr JR, Cooper WC, Reece PC (1947) An investigation of flower formation in adult and juvenile citrus trees. Amer J Bot 34: 1-8.

89. Goldschmidt EE, Aschkenaki N, Herzano Y, Schaffer AA, Monselise SP (1985) A role for carbohydrate levels in the control of flowering in citrus. Sci Hort 26: 159-166.

90. Cutting JGM, Lyne MC (1993) Girdling and the reduction in shoot xylem sap concentrations of cytokinins and gibberellins in peach. J Hort Sci 68: 619-626.

91. Mamun AA, Rahman MH, Rahim MA (2012) Effect of shoot bending and fruit thinning on productivity of guava. J Environ Sci Natural Resources 5: 167- 172.

92. Bagchi TB, Sukul P, Ghosh B (2008) Biochemical changes during off-season flowering in guava (psidium guavaja L) induced by bending and pruning. J Trop Agri 46: 64-66.

93. Mantur SM, Bagali AN, Patil SR (2005) Influence of bending and pruning of different varieties- of roses under naturally ventilated polyhouse. Karnataka J Agric Sci 18: 474-477.

94. Boora RS, Dhaliwal HS, Arora NK (2016) Crop regulation in guava- A review. Agricultural Reviews 37: 1-9.

95. Mahalle SS, Ingle HV, Sable PB (2010) Influence of plant growth regulators and chemicals on yield and quality of Hasta bahar in acid lime. Green Farm 1: 285-287.

96. Raturi GB, Hiwale SS (1991) Regulation of cropping in pomegranate under rainfed conditions. Indian J Hort 48: 13-15.

97. Abubakar AR, Ashraf N, Ashraf M (2012) Effect of plant bio stimulants on flowering, fruit drop, yield and return bloom of pomegranate cv. Kandhari Kabuli. Asian J Hort 7: 473-477.

Author Affiliations

Top

[1]*ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India*

[2]*Date Palm Research Station, Sardarkrushinagar Dantiwada Agricultural University, Mundra-Kachchh, Gujarat, India*