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An overview on Off-Season Flowering in Perennial Horticultural Crops

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ABSTRACT

The COVID-19 pandemic has significantly increased public awareness of the health and nutritional benefits associated with various horticultural crops, including fruits, vegetables, and medicinal plants. Consequently, these high-value crops have become integral components of daily diets. However, many perennial horticultural crops are typically seasonal, with fruits available only during specific periods of the year. This leads to a substantial demand for these crops during off-season months. Notably, late and early maturing varieties command higher prices in the market due to an overall decline in production during off-seasons. Off-season cultivation offers economic benefits by increasing farmer income, improving living standards, and ensuring year-round consumer access to these essential crops. Consequently, researchers have turned their attention to the importance of producing seasonal horticultural crops outside their main seasons to meet off-season demand. Over the past few decades, numerous studies have focused on the flowering and fruiting mechanisms of perennial horticultural crops, exploring techniques to manipulate them based on specific requirements. The authors of this article provide an overview of the flowering mechanisms of perennial horticultural crops, delving into various techniques for manipulating flowering periods. These techniques include considerations of temperature, photoperiod, chemicals, hormones, nutrition, agronomic practices, and advanced technologies such as molecular breeding and CRISPR/CAS. The hope is that this article contributes valuable insights for researchers in the field of off-season crop production.

Key words : *Off-season, Flowering, Temperature, Photoperiod, Nutrition, Pruning, Physiology, Hormonal regulation, Mulching, Bahar treatment, Perennial horticultural crops*

Introduction

Perennial crops are those which are long lived, preferably more than two years. Horticultural crops were broadly grouped into three categories of annuals, biennials and perennials. One of the characteristic behaviors of perennials is their unique flowering and fruiting habits. The perennial horticultural crops such as majority of fruit trees, plantation crops, tree spice and some vegetable crops *viz*., drumstick are seasonal, producing peak flowering in a specified month of a year. Though some of the crops bear flowers and fruits throughout the year, they were adjusted by the mankind such that a glut production can be obtained during its peak bearing time which is said to be the crops season in a year. As a result of this most of the commercially valued horticultural crops became unavailable in the

unseasonal months leading to the demand and supply gap, resulting in very high market price of the commodity. Thus, inducing off-season flowering or flower forcing in commercial perennial horticultural crops gains importance.

Off-season crop cultivation is the growing of certain crops which differ from the regular cropping cycle. Using moringa as an example and to throw light on the importance of off-season production which goes like this, in South Indian conditions, normally moringa crops attain the bearing stage during summer in March-August due to the prevalence of dry climate and less water requirement for crop growth and there will be less price for the produce in the market due to high production. But, during September to -October, productivity gets decreased and so the price rises in winter months. November to March is the offseason period, in which very little production is achieved and this may be due to the cause of more rainfall which causes flower drop and in turn, a smaller number of pods formed and poor fruit set is observed. Moringa prefers a dry climate for flowering and fruit set. Hence by studying the physiological and biochemical basis of off-season flowering in Moringa, one can understand the factors responsible for flowering in a normal season and will make a study to bring the solution to make the off-season flowering in moringa.

Off-season crop production would increase the farmer's income, the standard of living, and the produce is made available to the consumers throughout the year, growers can learn specific techniques of crop production, strengthens foreign exchange, can reduce the wastage of on-season production by avoiding the glut production of commodity and generates employment for the farm laborers throughout the year. Flowering can be manipulated and induced in the specified period by altering and considering certain factors like temperature, photoperiod, flowering behavior, use of chemicals and plant hormones, nutrition, agronomical practices like canopy management by training and pruning, inducing stress, varietal variations, breeding off season varieties using advanced technologies like molecular breeding, biotechnological tool, CRISPR/CAS etc. (Sharma *et al.* 2019). These factors are discussed individually in this article to highlight the existing knowledge in the flowering mechanism and their manipulation and hope this will be helpful for the scientific community engaged in this field of research.

Climatic Factors

Temperature / photoperiod

Temperature and photoperiod predominantly influence floral initiation. In most perennial, fruit crops, temperature plays a prominent role in flower induction. Many studies have also reported that cool temperature either 18°C in daytime or 10°C in night time initiates the flowering than the short photoperiod conditions and warm temperature either 30°C in daytime or 25°C in night time favors floral induction than long photoperiodic conditions. Florigen is a flowering hormone that contains gibberellin that is needed for the flowering of long-day plants and anthesis that is needed for the flowering of short-day plants. Many research studies on mango have shown that florigen is synthesized continuously in the leaves of mango trees when exposed to cool temperatures. Temperature requirement is a major phenomenon for the development of more inflorescence primordia. Temperature requirement varies with the crop cultivar. Light intensity is also a major factor. A high level of shading reduces fruitfulness. Response of crop to light requirement varies with the cultivar. Kennedy *et al.* (2009) have quoted that 90% relative humidity and low night temperature during the period of the southwest monsoon, as it provides well-distributed rainfall and high soil moisture during off-season plays a major role in the conversion of residual food reserve in young shoots into flower primordia. Critical day length is necessary for plant growth and development.

Davenport (2003) has also reported that flower induction in some of the cultivars takes place due to the presence of continuous warm temperature with high soil and atmospheric temperature in low altitude tropics. In mango, when a crop is exposed to a high temperature of more than 20 °C, it initiates vegetative growth and low temperature less than 15 °C induce flowering (Nunez-Elisea and Davenport, 1991). Time of exposure of the plant to certain light intensity has a major influence on flowering and fruit development. For mango, the monthly minimum temperature of 29.9 °C to 32.9 °C favored the flowering and fruit set in off-season mango cultivation under Kanyakumari conditions. Well distributed monsoon period with high relative humidity (90%) and low night temperature during southwest monsoon favors conversion of residual food reserve to floral primordial in the young shoots and it is a major factor that induces flowering.

The ideal climate for Kanyakumari's development of a regular off-season crop may have fairly evenly distributed rainfall. In the low-altitude tropical regions, where temperatures are consistently warm and soil and atmospheric moisture levels are high, several cultivars blossom irregularly (Davenport, 2003).

The interplay between low temperatures and the hour of vernalization could cause off-season flowering and speed up the flowering process. The three flowering genes VRN5, FT, and SOC1 could also be upregulated by vernalization, suggesting that they played a role in the subtropical strawberry cv. Pharachatan 80's increased flowering percentage, inflorescence count, and flower production, all of which were higher than in unvernalized plants. The vernalization process can be used to produce strawberries outside of the growing season and gives information on gene expression for subtropical strawberry molecular breeding (Thammasophon *et al*., 2023)

Nutrition

The high amount of nitrogen application induces more vegetative growth, hence by limiting the nitrogen fertilizer application, unwanted shoot growth is minimized and flower induction takes place. A crucial nutrient called phosphorus helps plants grow buds and bloom by promoting and strengthening these processes. In grapes, Phosphorous initiates bud formation and fruitfulness by enhancing the vigor of the vine. Therefore, fertilizers formulated for flowering are often higher in phosphorus than nitrogen and potassium. For the formation of inflorescence primordium, nitrogen source is the predominant nutrient and these nitrogen reserves are utilized for the growth of shoots. Potassium nutrient is involved in enzyme activation and carbohydrate metabolism thereby increasing the vine yield.

Physiological Basis of Off-season Flowering

The most important step in the flowering process is the conversion of the vegetative stage to the reproductive stage. In order to induce the flowering during the off-season, certain detrimental factors like temperature, rainfall, and relative humidity are to be considered. A large amount of sugar accumulation, starch reserve, total carbohydrates, carbon, and nitrogen ratio(C/N) in the vegetative shoots also promotes flowering. Sucrose assimilates cause some biochemical and cellular changes and promote floral induction. Carbohydrate and protein levels are necessary for flower induction. Davenport (2009) has reported that there occurs a narrow variation in carbon assimilation in regular bearing varieties in mango compared to the irregular ones. Heavy crop load and more vegetative growth during flower bud differentiation, high gibberellin level, and imbalance C/N ratio is the major reason for biennial bearing in alternate bearing mango variety. Amrapalli recorded a high accumulation of total carbohydrates, total protein content, acid hydrolyzable polysaccharides, and less amount of reducing sugars at the time of floral initiation. Biophysical parameter changes observed were more diffusion resistance capability which has shown better stomatal activity during flower bud differentiation time in regular bearers. A high rate of protein and carbohydrate synthesis takes place in regular bearing cultivars compared to irregular mango varieties. Also, accumulation of high photosynthetic chlorophyll (a, b) pigment content, total sugars, nitrate reductase enzyme activity which is responsible for nitrogen metabolism and ethylene production were recorded in regular bearer 'Amrapalli' variety at flowering stage (Singh and Sharma, 2008).

In annual moringa cv. PKM- 1, heading back at 70 cm followed by pinching at 100 days after heading back has recorded the high total chlorophyll content in leaves (Divyabharathi *et al.* 2020). Regulation of flower initiation by raising root zone temperature and preventing rainwater entry by the use of black polyethylene film mulch, pruning at the appropriate time, and foliar application of growth retardants in such a way that maximum flowering can be stimulated in the rainy and winter seasons to get fruits over the offseason. Sharmila Bharathi *et al.* (2018), have studied the effect of canopy management and chemical application on off-season flowering and fruiting of moringa. Among the different pruning methods, September pruning has recorded the earlier flowering in 78.10 days which is followed by July pruning, which starts flowering in 81.88 days. With the prevailing climatic conditions, September pruning has enhanced the IAA at the flowering stage and it resulted in early flowering in the crop. The combined effect of uniconazole 50 ppm and black polythene mulch promoted early flowering in Moringa in 70.91 days and the combined effect of Mepiquat chloride 50 ppm and black mulching has initiated early flowering in 72.45 days. These growth retardants like Uniconazole inhibits GA synthesis

and retards the shoot elongation thereby reducing the unwanted plant growth and development (Voon *et al*., 1991). The anti-gibberellin activity was by preventing the conversion of kaurene to kaurenoic acid. It stops the function of kaurene synthetase which aids in conversion. All the three combined effects of uniconazole 50ppm, black polythene mulch, and July pruning have shown the earlier flowering in moringa in the off-season in 66.25 days. In this treatment, mulching has increased the root zone temperature which favors the physiological and metabolic process in plants thereby it increased the total number of panicles per tree. In mango trees, soil drenching of Paclobutrazal@3ml/m canopy diameter during August 3rd week has induced the early flowering in Totapuritrees.

Biochemical Basis of Off-season Flowering

In guava, bending and pruning is practiced to induce off-season flowering. Bending is done in 8-10 lateral branches per plant before 45- 60 days of flowering and these branches are tied to the base of the plant using the rope. After 2 to 3 days of bending, NAA @ 0.5 ml/l of water and metacid @ 1ml/l were applied to the bent portions and after 19 days, new shoots were formed from these bent portions. Also, pruning was done by removing the old leaves. Samples were taken from these plants and different biomolecules and enzymatic activity were estimated. According to Torit Baran Bagchi *et al.* (2008), bending has shown an increased level of total free amino acids, tryptophan, and proline accumulation and low phenolic content. After this practice, at the initial stage, a high level of lipids was found in the barks and at a later stage, high lipids were found in leaves. This shows that plants adaptability to overcome this bending and pruning shock. The analysis has reported that a high level of TSS (Total Sugar Solids) and high reducing sugars were found in the stressed (bent/pruned plants) plants. High enzymatic activity of catalase, peroxidase, polyphenol oxidase, and more proline content were found analyzed in the stressed plants. These enzymes are involved in plant defense mechanisms and act as oxygen scavengers during photosynthesis under stress conditions. Paclobutrazol is a growth retardant that inhibits the growth of vegetative shoots and promotes flowering by inhibiting the gibberellin synthesis. It can combine with iron-containing enzymes like catalase (CAT) and POD (Polyphenol oxidase) which provides more tolerance to oxidative damage caused by stressful conditions in plants and is also useful to metabolize and detoxify the inhibitory compound generated during the flower development and also increase the antioxidative enzyme activities which promote flower induction (Saxena *et al.,* 2014). It has been also reported that paclobutrazol application has accelerated the movement of protein to the sink (fruits) which in turn reduced the total soluble protein content in leaves. In regular bearing mango cultivars, protein level was found to be maximum at even before the FBD stage than the irregular ones and gradually reduced at FBD stage and bud burst stage due to its mobilization for promoting flowering and then significantly increased during the panicle elongation stage in regular bearers. Urban *et al*. (2004) has reported that during flower induction, a high amount of protein, carbohydrates, and nitrogen accumulation takes place which favours profuse flowering in crop plants. It was discovered that sugar concentration decreased throughout the flowering period; this might be because decreasing sugar levels were higher and the insoluble portion of the carbohydrate was converted into a soluble form during the flower bud differentiation stage (Saxena *et al.,* 2014). In annual moringa cv. PKM- 1, heading back at 30 cm followed by pinching at 100 days after heading back has promoted the light perception thereby increasing the auxin, cytokinin level, and nitrate reductase activity. This has also resulted in the accumulation of high soluble protein content and increased the activity of RUBP carboxylase activity thereby increasing protein synthesis. Also heading back at 70 cm followed by pinching at 60 days after heading back has elevated the phenolic compounds that are involved in metabolism, growth, and development in plants. This high phenol accumulation may be due to high IAA and lower IAA oxidase in the pruned trees (Divyabharathi *et al.,* 2020).

Suryanarayana (1978) has experimented with the application of cycocel 5000 ppm in Mulgoa mango trees and found a decreased level of glucose and fructose in both the leaf and stem, and high sucrose and protein were observed in the shoots treated with growth retardant thereby it increases the number of flowering shoots in treated mango trees. Kumar *et al.* (2014) has reported that offseason flowering in Mango in certain blocks of Kanyakumari and Thirunelveli districts of Tamil Nadu is mainly due to the cause of environmental factor and have also said that during off-season flowering, high chlo-

rophyll content, Carbohydrate: Nitrogen ratio and carbohydrates accumulation was observed in both the leaf and stem at vegetative, flowering and harvesting stages of the crop. Also, less IAA oxidase activity and gibberellin synthesis were observed during the 'off' year compared to the 'on' year growing season. They also found that mango trees were more sensitive to temperature changes than to photoperiods, as indicated by the varying timings of blossoming in different parts of India.

Hormonal Basis of Off-season Flowering

Plant growth retardants like paclobutrazol restrict gibberellin production, which can cause mango and citrus to bloom. Mango, citrus, and mangosteen trees have been made to produce off-season flowers after being treated with paclobutrazol and then treated with a dormancy-breaking substance. Mango trees may be induced to flower at any time with this method, and mangosteen trees started flowering three months earlier than the control tree. Time of application is a major factor to be considered for flower-inducing chemicals to get the best results. In grapevines, Chlormequat chloride is used to promote flowering which aids in the formation of inflorescence primordium. High cytokinin activity was observed during budburst and flowering, this is due to the role of this hormone in the regulation of reproductive growth in grapevine (Buttrose, 1974).

In mango, flowering is regulated by hormonal control which induces shoot formation and it leads to the development of reproductive shoots. The starting cycle appears to be regulated by a proportion of endogenously controlled phytohormones, likely to be the production of auxins from leaves and cytokinins from roots, independent of influential factors. At the point of shoot induction, the balance between a temperature-regulated florigenic promoter and an age-regulated vegetative promoter determines whether reproductive or vegetative shoots are induced. Davenport, (2007) has reported that off-season flowering in mango trees is managed in the tropics by successfully integrating shoot initiation using tip pruning and nitrate sprays, as well as managing stem age to induce flowering during any desired week of the year. Ravishankar (1987) studied the assimilate partitioning, in which ^{14}C-Sucrose translocation assimilation pattern in alternate bearing mango Alphonso and regular bearer variety Totapuri in both the pre and post FBD (Fruit Bud Differentiation) was studied. This study has reported that high sink strength and very active metabolic activity were observed in Totapuri mango. It is due to the balanced distribution of acropetal and basipetal ^{14}C-Sucrose photo-assimilates which increased the metabolic activity and expression of flower regulator genes at the fruit bud differentiation stage and caused the floral initiation in mango. But, in the case of Alphonso, due to the high acropetal to basipetal ^{14}C-Sucrose translocation ratio, it led to metabolic blockage and no flower regulating genes were expressed properly resulted in off-season flowering. To overcome this factor, paclobutrazol, a plant growth retardant that has anti-gibberellin properties which reduce the shoot growth, blocks the synthesis of flower inhibitors, and promote the expression of flower promoting factors is widely used nowadays to regulate flowering.

Growth Retardants

According to Tripathi and Dhakal (2005), application of paclobutrazol @ 5 ml/tree around the collar region of the citrus tree advanced the flowering to more than two months from normal growing season and increased the number of flower shoots and fruit set. He concluded that paclobutrazol should be applied at earlier dates than in later dates for attaining effective off-season flower induction in acid lime (*Citrus aurantifolia* Swingle) landraces, two Nepalese, and one commercial Indian landraces under Chitwan conditions**.**

Paclobutrazol@ 1000 and 1500 ppm induced early flowering in Durain cv. Cha-nee by suppressing the shoot growth and thereby increasing the yield (Chandraparnik *et al.,* 1991). Ethepon and potassium nitrate are used for off-season flower production in fruit crops like mango. Potassium nitrate is widely used in Phillippines to produce early flower induction and fruit set in mango cultivars 'Carobao' and Pico' (Madamba, 1978). KNO_3 application at 4% induced early flowering in treated trees compared to control trees by increasing the number of flowering shoots per tree (Maloba *et al.,* 2014). Kulkarni (2004) claims that when buds are stimulated in response to KNO_3, the floral stimulus is present in the stems and that KNO_3 may sensitize buds to the floral stimulus. When 4 % KNO_3 spray was given to two-month-old stems, Davenport (2003) observed 100% vegetative shoots, whereas when the same spray treatment was applied to 4.5-month-old stems on orchard trees, 100 percent re-

productive shoots were observed. According to Maloba *et al.* (2014), application of 4% KNO_3 and 1,000 ppm Ethepon has shown early flowering and fruit set in 'Apple' and 'Ngowe' mango trees. The use of paclobutrazol in combination with plastic mulching prevents rainfall infiltration into the soil and it can be used to induce flowering in durian. Ringing treatments caused rambutan trees to blossom and yield fruit in the off-season period.

The ringed trees began to flower 4 months before the control trees, with no difference in inflorescence size or number, or the number of flowers per inflorescence (Poerwanto, *et al.,* 2008). In mangosteen, the application of 2 g a.i./tree of paclobutrazol applied by soil drenching also induces off-season flowering. Matsumoto *et al.* (2007) has shown that Potassium chlorate ($KClO_3$) and Sodium hypochlorite (NAOCl) application induces flowering in Longan fruit trees. Following cool temperature treatment, cytokinin (CK) concentrations in buds increased in both $KClO_3$ induced longan and litchi, but gibberellin (GA) and auxin (IAA) concentrations decreased. High cytokinins to IAA ratio in buds, found to be essential for the activation of FI on the gene level (Hegele *et al.,* 2008).

Ito *et al.* (2001) has resulted that the application of maleic hydrazide, a growth retardant in Japanese pear (*Pyrus pyrifolia*) has elevated the cytokinin level and promotes floral initiation. The endogenous application of GA inhibits floral initiation in the grapevine. Plant hormone cytokinin also engaged in floral initiation. In litchi, cytokinin initiates floral bud differentiation and formation. Foliar application of MH 500 ppm after fourth month of planting in annual moringa cv. PKM 1 has recorded early flowering in 68.21 days, more number of panicles (47.63). more number of flowers per panicle (53.95) and resulted in good fruit set and yield (Jeyakumar *et al.* (2003).

To get off-season flowering and production in annual moringa cv PKM 1, Anbarasu (2009) recommended taking up seed sowing on May 15th followed by foliar spray of Nitrobenzene 0.5 percent. Kalicharan (2012) observed that pruning on July 15th, followed by two applications of 50 ppm Mepiquatchloride one and two months after pruning, resulted in an off-season production in annual moringa cv. PKM1. Studies of Hau and Hieu (2017) have declared that foliar application of Paclobutrazal@1000 to 1500 ppm initiated off-season flowering with an increased number of inflorescence per tree, more number of flowering branches per tree and uniform flowering in durian cultivars RI 6 and Monthong.

CROP REGULATION - Moisture stress (Bahar treatment)

Providing soil moisture stress for a certain period promoted flower bud development by reducing the growth of vegetative shoots. This kind of management practice also manipulates the flowering mechanism in moringa. Moisture stress alters stomatal conductance, resulting in a decrease in the availability of internal CO_2 and hence photosynthesis, leading to a reduction in leaf, stem, and root elongation (Vos and Groenwold, 1989). As the leaf water potential decreases, the rate of elongation decreases. The methods of withholding water, exposing feeder roots, and trimming fibrous roots to promote blossom in the appropriate season are done in the guava growing belts of Maharashtra and the Deccan plateau in India.

According to Suresh Kumar *et al*. (2020), in sweet orange cv. Sathgudi, withholding of irrigation for 25 days before flowering in August and September until it shows the yellowing and wilting symptoms is done to induce the formation of more vegetative shoots and profuse flowering buds in October and fruiting takes place in April- May, which offers good price to the produce in this season and farmers can make more profit by adopting this method. During this rest period, more carbohydrates and other food materials accumulation takes place in the plant tissues and followed by the supply of recommended irrigation and nutrient rates enhance the shoot growth and flowering shoots. According to broad consensus, in litchi, high soil moisture in the autumn induces vegetative development and inhibits blooming, whereas low soil moisture limits vegetative growth and encourages flowering. Studies by Iwasaki (1959) have shown that root pruning in citrus has initiated early flowering.

Canopy Management / Pruning

The optimal pruning produces better growth conditions in terms of light, nourishment, and moisture, resulting in the early onset of the reproductive phase and the formation of more fruits. The potential of the growth retardants to delay vegetative growth and enhance blooming in agricultural plants is well-known. The apical dominance was eliminated, lateral buds were relieved from correlative inhibition, and the tree's structure and construction

were modified as a result of the pruning operations. As a response, flower-bud initiation in lateral buds was accelerated, resulting in higher yield production. Sometimes inhibitory substances in the immature shoots of plants also prevent the floral initiation, hence by pruning these shoots, inhibitory action is removed and it is done by exogenous GA application which leads to the emergence of new panicles and flowering shoots. Sharma *et al*. (2006) have reported less chlorophyll content in pruned trees than the unpruned mango trees. Pruning the annual moringa cv. PKM 1 after 60 and 90 days after sowing has resulted in high chlorophyll content, high IAA oxidase content, and relative water content than the control.

An experiment was conducted in HC&RI, Tamil Nadu Agricultural University, Periyakulamwith staggered sowing followed by application of chemicals and pruning the moringa trees followed by chemical application has proven that they induce flowering and fruit set in moringa during the off-season. These staggered crop sowing was taken in different months in April, May, June, and July. After 25 days of sowing, the first pinching was done, and following this chemical like 0.5 % potassium nitrate, 0.1% salicylic acid, 0.5 % calcium chloride, and 0.5 % nitrobenzene were applied as foliar spray two times at 15 days interval. Among all these treatments, sowing in the month of May followed by nitrobenzene and potassium nitrate application induces a high number of flowers per panicle, number of panicles per plant, and early flowering in 88 to 91 days respectively. It has also shown improved total soluble protein, chlorophyll content, relative water content, and nitrate reductase activity. Another experiment in which one-year-old trees were chosen with different pruning levels in different months during May, June, July, and September were carried out followed by pinching the newly sprouting branches and then chemical spray of potassium nitrate 0.5% salicylic acid 0.1%, calcium chloride 0.5% and nitrobenzene 0.5% was taken. Among these treatments, trees that were pruned in July followed by application of potassium nitrate 0.5% has observed the greater number of flowers per panicle, a number of panicles per tree, and high pod yield.

In moringa, pinching after 90 days of sowing has shown increased pod calcium, potassium, iron, ascorbic acid, pod protein, crude fiber, and carotene (Vijaya Kumar, 2001). Pinching after 80 days of sowing has increased the total number of flower clusters per tree (46) and also more numbers of flowers per panicle (102) in moringa cv. PKM 2 (Devi *et al.* (2003). Animesh Sarkar and Bikash Ghosh (2006) found that pruning the branches to 20 cm from the tip improved the number of new shoots per branch, the number of flower buds per branch, the number of fruits per shoots, and the yield in guava cv. Sardar.

Mamun *et al*. (2012) have reported that shoot bending in guava during October initiates early flowering and sets good quality fruits. Bending is carried out in an antigrowth direction at a 90^{o} angle and it creates tension in the wood portion thereby reducing the phloem formation and products of photosynthesis are transported all over the plant organs and the C: N ratio is maintained which favors floral initiation and fruit set.

Thinning / Deblossoming

This practice is done during the normal growing season to promote flowering in the 'off-season. Many types of chemicals or growth regulators such as NAA, 2, 4-D, carbaryl, NAD, and etherelare used for deblossoming. These are found very effective in reducing the number of fruits thereby increasing the fruit quality. Numerous studies have shown that implementing this practicein rainy season crops has increased the winter crop. Studies of Al Ekram*et al*. (2019) have shown that 80% of fruit thinning in the off-season crop resulted in the high-quality superior type of fruits but only less production is recorded. The fruits obtained during the season are of poor quality but recorded high production.

Mulching

Root zone temperature is also a major factor for pod development in the off-season. Black polythene mulch can be used to increase the root zone soil temperature by 2.4 ^{0}C to 4.6 ^{0}C at 5 cm depth and 2.1 ^{0}C to 3.5 ^{0}C at 10 cm depth which favors better pod development in off-season moringa. Sharmila Bharathi *et al.* (2018), have studied the effect of canopy management and chemical application on off-season flowering and fruiting of moringa. Different mulching and pruning methods are followed to find its effect on off-season flowering in Moringa. This study has declared that among the different mulching treatments adopted in the experiment, the plants with black polythene mulch come to flowering earlier in 72.78 days. Significantly, the same treatment has also shown more yield per tree. Black polythene

mulch has initiated more flower formation in the rose plant (Tripathy *et al.*, 2019). This mulching has elevated the soil temperature and provided the favorable climatic requirement for the crop which has fastened the crop growth and development and started flowering earlier. According to Attallah (2016) plastic PE mulch has initiated the advanced flowering in off-season production of summer squash varieties. Studies of Hau and Hieu (2017) have reported that plastic mulching has induced earliness in flowering during the off-season production of durian.

Molecular Breeding

Wang *et al*., (2020) conducted a metabolomic analysis that showed an increase in soluble sugars (fructose, glucose, maltose), organic acids (citric acid, alpha-ketoglutaric, succinic acid), and amino acids (aspartic acid, glutamic acid, phenylalanine), and increase of tricarboxylic acid cycle increase and phenylpropanoid accumulation essential for breaking bud dormancy to promote flowering. Through a careful examination of the intricate metabolic and molecular regulatory processes involved in early flowering and off-season flowering, they came to the conclusion that blooming genes would enable plant regeneration in a greenhouse with the potential for year-round growth. Utilizing early flowering genes will enable progeny to carry those genes, expediting the breeding process for perennial crops.

Biotechnological Tool

The combinatorial method combining genomics with rapid cycle breeding techniques will show to be a powerful tool for accelerating and lowering the cost of conventional breeding, which will improve perennial crops. Therefore, a starting point for showing the genetic diversity and variation that currently exist on a genome-wide scale is provided by the rapid development of next-generation sequencing technologies and bioinformatics tools. These tools also provide milestones for enhancing the agronomic traits in perennials. Functional genomics studies on the genes influencing flowering or fruiting features in perennial fruit crops will be conducted to obtain year-round production and in off seasons (Velasco *et al*., 2010)

Crispr/Cas9 Technology

CRISPR/Cas9 technology has so far been proven to be effective in horticulture plants when it comes to genome editing. Numerous fruit, berry, and ornamental plants have had their genomes successfully modified. These plants' genomes have been edited in order to change the timing of fruit ripening and off-season flowering, increase plant resistance to biotic and abiotic stresses, and enhance the growth characteristics of plants as well as the flavor of their fruits. Novel, better technologies for editing and simultaneous activation of gene transcription, which is important for the development of novel types of horticulture plants, as well as modified enzymes for more effective genome editing are now available. The molecular insights of the genes involved in the flower and fruit induction in several fruit crops are studied but still it is very limited (Rukavtsova*et al.*, 2022).

Conflict of Interest: None

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