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RECENT TRENDS IN CROP REGULATION AS A BASE OF ROUND YEAR FRUIT PRODUCTION FOR PROFITABLE MARKET RETURNS TO GROWER : A REVIEW

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ABSTRACT

Some of the fruit crops, such as guava, pomegranate, lemon, mandarin, and other crops, bloom throughout the year without going into the rest period and produce 2-3 bahars, but the yield and quality are not up to the mark in all the harvest. Crop regulation is the purposeful alteration of the basic flowering process of the fruit crops to produce regular and quality fruit crops. For achieving crop regulation, various practices are being adopted, such as withholding of irrigation due to which the tree sheds its flower and goes into rest. So, it becomes quite essential to understand the flowering and fruiting behaviour in crops and which bahar will give out the best crop and own the highest returns to the grower. To provide a wide variety of fruit to fulfil the daily requirement, the off-season fruit/ year around the production is an essential part of the fruit industry. Seasonality in fruit production is a significant factor contributing to high postharvest losses reported in the value chain. Oversupply during the high season is one factor contributing to the high postharvest and monetary losses to the growers. The supply exceeding the demand leads to wastage at the market level. So, this scenario in the fruit production industry necessitates developing technologies and practices, which would help in year-round production to tackle the problems associated with seasonality in fruit crops.

Key words : Crop regulation, Bahar, Flowering, Offseason, Fruit seasonality.

Introduction

For harvesting regular and high-quality produce, one has to keep low crop density. Crop density is a measure of the number of fruit/ flowers which is born in per cm^2 area of that particular crop. Crop regulation is mainly dependent on flowering and fruit sets. Crop regulation also tends to extend the production season, which helps to achieve year-round fruit production and diversifies the consumer's choice. There is an enormous method of crop regulation ranging from chemical to mechanical. Few fruits can flower throughout the year such plants produce 2-3 flowering in the year and do not have any rest period although this allows the plant to have all year round production, but have the drawback of poor quality and irregular harvesting due to which it is advisable to go for only one harvesting suiting the production factors (Agusti *et al.*, 2022). Crop regulation is a complex process as different factors control flower induction. For using crop regulation as a method of quality improvement, one has to have knowledge of flowering and fruiting behaviour of the crop and which bahar will help us have the best quality crop keeping in mind all the factors associated with particular bahar. The lean period of acid lime is from July to August, whereas we know that acid lime blooms

throughout the year and the main blooming period is Feb-March. Particularly in lime flowers, fruitlet develops into fruits and mature fruits simultaneously (Rajput and Babu, 1985). Use of cycocel 1000 ppm on monthly interval before bud initiation of flowering, *i.e.* in August and September, which produced maximum yield in terms of the number of fruits per tree and weight of fruit per tree and this treatment also improve the fruit quality to juice %, TSS, acidity, ascorbic acid content and peel% (Mahalle *et al*., 2010). Similar trends are also recorded in guava, with varying amounts of fruit throughout the year.

Guava has three distinct flowering seasons Ambe bahar, mrig bahar and hastha bahar. Ripening time in north India, mostly coincide with the rainy season (July to mid-October). From November to mid-February (winter season). Lal *et al.* (2013) reported two blooming seasons in the climatic state of Assam. The rain season brings a good yield, but it also brings poor quality, insipid taste and high pest infestation (Rathore and Singh, 1974; Singh *et al.*, 1996; Rawal and Ullasa, 1988). When fruits are produced out of their regular cropping cycle, they fetch better market prices than those produced in the regular growing season (Singh *et al*., 2000). However, the fruits produced in the winter season are of better quality than the guava fruit produced in the rainy season due to the high incidence of infestation of pests and diseases (Sharma *et al*., 2020). The rain season fruits have a watery, insipid taste and poor nutritional value (Syamal *et al*., 1980).

Singh *et al*. (1991) carried out intensive studies on guava cropping patterns and recommended a single winter crop every year to produce fruits, ensuring higher returns to growers. Many methods have been tried to ensure that the crop stays in the vegetative phase during the rainy season to obtain a better-quality crop in winter (Shigeura and Bullock, 1976). Proper management of flowering can help maintain a supply almost throughout the year (Manica *et al*., 1982; Lopez and Perez, 1977 and Shatat, 1993). Lal *et al.* (2017) reported that guava bears fruits on current season growth, so its harvesting season can vary according to the prevailing weather conditions and cultural practices. To impact flowering in guava, primarily used techniques are irrigation, fertilization defoliation and pruning (Singh *et al*., 2018; Shatat, 1993; Shigeura and Bullock, 1976). Whenever, we force the crop to grow out of its regular growing cycle, it can be regarded as to of season fruit production. Although of season fruit production has been related to many production constraints such as low yield, high production cost, higher crop failure chances and high incidence of pests and diseases. As there are constraints in offseason production, few growers prefer producing off-season crops due to the five times higher returns offered after selling off-season crops. Opting for off-season crop production also helps avoid a glut in the market at the peak of the harvesting season. As the supply during peak season is monitored and kept under control, it will help regulate the market and reduce post-harvest losses.

This review has been done to assess and analyze the effectiveness of various crop regulation practices in fruit crops such as guava, pomegranate, lemon, mandarin, and others, aimed at achieving regular and quality fruit production throughout the year. Major objective encompasses the need to understand flowering and fruiting behavior in these crops, determining optimal bahars for maximum yield and quality and addressing the challenges associated with seasonality in fruit production. The review could delve into various practices such as irrigation withholding and their impacts on crop regulation, as well as explore emerging technologies and practices aimed at enabling year-round fruit production to mitigate postharvest losses and avoid major market wastage by regulating the production according to market requirements.

Need for crop regulation?

Some crops bloom all year, but the difficulty with such trees is that they do not provide a high yield or quality. The bahar is chosen based on the needs of the place and crop. For example, in north Indian conditions, the crop of ambe bahar is impacted by heavy rainfall and fruit fly infestation; however, the crop of the winter season is not affected by such difficulties. Crop regulation methods are determined by climate conditions, cropping patterns, and cultivars native to that region. Guava generates a bountiful harvest during the wet season because of high flush growth throughout the summer. High temperatures and heavy rains shorten the harvesting window, causing a market oversupply and a low price for growers. Superior quality fruits are acquired in the winter, resulting in a better price for the farmer. Fruit flies attack rainy season fruits, reducing quality and rendering the fruit unsuitable for human consumption. So far, it is best to harvest crops throughout the winter season and avoid growing fruits during the wet season. Pomegranate growers confront a constraint, *i.e.* scarcity of water in states such as Maharashtra, Rajasthan and Gujrat. In pomegranate, ambe bahar is avoided and the crop target the mrig bahar season of harvest crop in winters; however, few farmers also aims to obtain hastha bahar flowering to harvest crop in January.

Crop regulation in different crops

Guava : (*Psidium gujava*) most commercialized fruit of subtropical Indian continent. This crop requires little or no care and can provide a better return to the grower. This crop needs low investment in comparison to other fruit crops grown. Guava offers flowering in 2 distinct seasons, *i.e.* spring (March- April) and rainy (June- July) time of ripening consider with rainy and winter seasons, respectively. The rainy season guava of north India is a high yielder, but poor quality and nutrition value also have a high insect pest infestation. Whereas, winter season fruit is high in regularity and are free from diseases and provide higher returns. To harvest high-quality fruit, it is advisable to manage the fruit tree so that they produce the crop only once. This requires the management of flowering to obtain the most desired crop by using methods such as withholding irrigation, pruning, thinning of flowers (chemically or mechanically). Growers usually prefer mrig bahar to harvest fruit during the winter season, free from pest infestation.

Pomegranate : Regular irrigation results in continuous flowering in pomegranate. These plants produce continuous flowers and bear small crops at different time intervals throughout the year, which is not desirable commercially. Bahar treatments are used to regulate flowering under such conditions. For this two month prior to the selected bahar, the irrigation is withheld and is followed by light mounding in a basin, resulting in the shedding of leaves. Medium pruning is also followed after 40-45 days of withholding irrigation. As soon irrigation is resumed, the plants are provided with the recommended dose of fertilizer. This provides the plants with profuse flowering and fruit production. The fruiting requires 4-5 months after full bloom.

Under tropical conditions, there are three distinct flowering seasons, *i.e.* ambe bahar (January- February), mrig bahar (June- July) and Hastha bahar (September- October). The flowering season selection is selected considering the availability of irrigation water, market demand and prevalent pest and diseases of that particular area. The ambe bahar fruits are ready for harvest from June to September. As the fruit development occurs during dry months, they develop an attractive colour and quality, thus suitable for exports.

The dry weather also reduces the incidence of insects and pests. However, harvesting ambe bahar requires assured irrigation facilities. Fruits of mrig bahar are ready by December to February and require relatively less irrigation as it is favoured by the rainy season at the time of crop development; however, the quality of fruit pertaining to sweetness and colour is highly affected due to high water uptake by the plant during rainy season. Hastha bahar fruits are harvested from March to April. They have a beautiful rind with dark colour aril. The fruit supply during this period is limited, so the fruits fetch a premium price tag. Withholding irrigation during this time is an arduous task due to the coincidence of rains with flowering and leads to more flower drops, causing poor yield.

Citrus Group : Under this group, lime, lemon and citron are privileged to bloom throughout the year, and spring bloom is the heaviest. The peak blooming season is February- March. Under tropical and subtropical conditions, they give continuous growth flushes throughout the year. Acid lime trees flower thrice throughout the year in January- February (Ambe bahar), June- July (Mrig bahar) and September- October (Hastha bahar), having 47%, 36% and 17% flowering, respectively (Maheswari *et al*., 2023). The hasth bahar fruits are ready by April-May during heavy demand and fetch a premium price. Due to monsoon rains preceding flower initiation and fruiting attained under uncontrolled conditions lead to low flowering percentage GA reduce flowering intensity during stress in the up coming flowering season. CCC was also reported useful for imparting flowering. Lal and Das (2017) reported that GA_3 @ 50 ppm effectively increased yield and quality of Allahabad safeda under Assam conditions. The stress hormones are found to have a close relationship with flowering and flowering response depends on the severity of stress (Kazan and Lyons, 2016; South Wick and Davenport, 1987; Barbera and Garimi, 1988). Webber (1943) reported the relationship of temperature with the time of flowering as the flowering of the temperate area is delayed than the flowering of higher temperature zone. Moti (1964) reported that Kagzi lime flowered only once under Saharanpur conditions (Devi, 2011).

Season influences flowering than the age of branch. However, the flower retention and fruit set is observed higher in June flowering than in January flowering (Hittalmani *et al*., 1977). Rohidas and Chakrawar (1989) studied ambe bahar under Maharashrtan conditions and reported early flowering (November) extending till February, having a duration of 50-55 days having its peak from 15th -31th January. Similarly, George *et al.* (2019) reported two flowering under Karnataka conditions 1st during December- January and 2nd during July- August. Under Akola condition, two major flowering seasons (December- February Ambe bahar and June- July Mrig bahar) were reported by Ghawade *et al*. (2002). The majority of shoots born flower was of standard vigour in

terms of shoot length and were present in the apical region. In central India, mandarin blooms thrice and such trees bear irregular crops with small fruits with poor yield. In order to get rid of this particular problem, the flowering has to be regulated so that we harvest the best possible crop in the season when a low supply and high demand is keeping in mind all the requirements of fruit production.

Principle of crop regulation

It is based on the simple principle of regulating the crop so that fruiting is obtained in the season with the highest demand and lowest supply of fruits. The crop needs to bear fruits on current season vegetative growth. The growth can be either new emergence of lateral buds on old stems or the extension of already established terminals of different sizes and vigour.

Objectives

Under crop regulation, the tree is forced to undergo rest and bloom under the best of three yearly flushes. This enables the grower to uniformly regulate the fruit quality and provide maximum profit to the grower. The use of crop regulation also reduces the cost of cultivation as if the crops produce continuous bloom and bears erratic fruiting will require multiple harvests causing high expenditure and overall maintenance, monitoring and marketing.

Method of crop regulation

In order to harvest regular, high quality and heavy yield of the crop, one has to modify the flowering behaviour of the crop, which can be carried out by using any of the following methods.

1. De-blossoming
2. Smudging
3. Withholding of irrigation
4. Root exposure/ root pruning
5. Nutrient application/ use of PGRs
6. Shoot bending
7. Shoot pruning

Bahar treatment

Bahar is a synonym for flowering. It is referred to a selection of any one of the three prominent flowering seasons, which is observed in a few crops such as Guava, Pomegranate, Citrus and grapes in a few areas. The methods for bahar treatment are similar to crop regulation as under.

De-blossoming/ thinning

Referred to as the removal of the flower to reduce the number to a lower extent either chemically or mechanically. Here, the number of flowers is reduced to keep them low to force the tree to flower in winter or maintain the leaf to flower ratio so that the fruit may not starve for the food material and a low number of quality fruits. Few workers effectively used chemicals for thinning out rainy crops and induced winter season flowering (Singh *et al*., 1990, 1991, 1996; Singh and Reddy, 1997). 96% de-blossoming was reported by Deshmukh (2022) on using NAA @ 100 ppm in Guava whereas, Chundawat *et al*. (1975) used NAA @ 100, 200 and 400 ppm reported 21, 54 and 82% de-blossoming respectively in Guava. Using 400 ppm of NAA, Pandey *et al*. (1980) obtained 100% success in Guava flower thinning. However, similar results were also reported by Singh *et al*. (1991) by the use of 1800 ppm ethephon accompanied by sprays of 1-2% potassium iodide. Dhaliwal (2002) reported maximum flower drop using 0.5% potassium iodide. Manual de-blossoming is equally effective if done in April-May and the tree becomes work potential to produce next flower in June-July, so are the fruits ready by November to February.

Few chemicals such as NAA, NAD, 2, 4-D, carbaryl and ethrel were found to reduce the rainy season and increase the yield and quality of winter crops. Manual removal of the flower is adequate but not practically possible on the commercial scale; however, it can be done on a small scale at an early age and on plants in the kitchen garden. Mixed success has been reported using NAA, NAD, 2, 4-D, potassium iodide, 2-chloroethyl phosphonic acid, 4, 6-dinitro-o-cresol (DNOC) urea. The results had different effects depending on cultivars, tree conditions, type of soil, and environment. Antony *et al.* (2020) provided findings on retaining lower flower load, which reduced the yield, but improved the fruit quality and shelf life of peach fruit. Even due to less yield, the returns gained by growers were high.

Withholding of irrigation

Reduction in the water availability to plants results in the development of temporary stress, which results in flower drop in plant and whenever we require flowering, one has to resume irrigation a month prior to the time when we want flowering in plants. Mancha *et al*. (2021) reported that using regular deficit irrigation and early cluster thinning resulted in a maximum gain of bunch weight under the semi-arid condition of Southern Spain.

Root Exposure/ Root pruning

Root pruning is referred to as a technique of crop regulation where roots are exposed to sunlight by removing the 7-10 cm soil around the 40-60 cm radius of the tree trunk. The water is withheld for one – to two months before flowering, which puts the plant under water

stress; the leaves show wilting symptoms and abscise from the tree. One month before flowering in the desired bahar, the roots are again covered with soil + FYM mixture, and plants are irrigated. The plants start new growth, profuse flowering and fruiting. The above practices must be avoided in light sandy and shallow soil and should be practised for only 2-3 weeks for inducing wilting and debilitation of trees. Under Indian conditions in summers, water availability is low, so growers prefer mrig bahar where plants are forced to rest during April-May, which reduce the water requirement and produce profuse flowering during July- August. Under Maharashtra conditions, root pruning resulted in heavy yield (Mehta *et al*., 2012). Kumar *et al.* (2010) exposed guava roots and pruned root hairs and kept plants under water stress, which resulted in defoliation of guava plants.

Shoot Pruning

Removal of terminal 20-30 cm portion of the branch from a tree is known as shoot pruning. Pruning should be done during April to avoid ambe bahar. Chemical usage may be ineffectual due to its reliance on various internal and external variables (*e.g.*, weather conditions) (Costa *et al*., 2018). In tropical fruits, severe pruning must be avoided. The current season's growth must be done to avoid the rainy season under north Indian conditions. Kumar *et al*. (2010), while evaluating the impact of pruning on peach productivity, research indicates that fruit yield reduces as pruning severity increases. He also said that when pruning intensity increased, the average size and weight of fruits, *i.e.* length and diameter, improved considerably.

The responses of a cultivar to varied pruning levels might be linked to the size of the leaves and the number of leaves per shoot, which affects the quantity of photosynthate. Dhaliwal *et al*. (2000) pruned 25-50% at different times (20 April, 10 May and 30 May) and reported low fruiting in the rainy season and increased winter season flowering in guava *cv.* Sardar. Tender shoot pruning about 4-5 inches from tip reduced rainy season flower drop. Agnihotri *et al.* (2016) reported that 75 % pruning of shoots in guava resulted in fruit weight 131gm and provided B: C ratio of 2.10. Shoot pruning was a good technique for effective crop regulation and produced the best quality winter guava by pruning at 45 cm from the base during June in guava *cv.* Lalit (Meena *et al*., 2017).

Chemical / PGRs Application

Chemical thinner is much cheaper and faster than manual thinning. These involve the use of blossom desiccator, growth regulators and photosynthetic inhibitors. In Europe, research is being conducted on the usage of ammonium thiosulphate (ATS) and the plant growth regulator 2-chloroethyl phosphonic acid (ethephon), both of which are routinely used on apple and pear trees in full bloom (Kurlus *et al*., 2020; Stern *et al*., 2014; Fallahi *et al*., 2006). The primary goals of the widespread usage of thinning in apple and pear production are to increase fruit quality and avoid alternate bearing. The benefit is that removing blooms and buds during the early stage of development enhances absorption, eliminating competition between the tree's vegetative and generative organs. As a corollary, the next year's growth is more robust, the fruit quality is better than the previous year, the production is higher and the flower buds responsible for blossoming in the following year are more differentiated (Kurlus *et al*., 2020). Schoedl *et al*. (2009) reported ATS as a widely used agent for thinned apple and peach blooms. However, it may have a phytotoxic impact on leaves, reducing photosynthesis and fruit size. Prabhu *et al*. (2017) from horticulture college and research institute TNAU obtained maximum average fruit yield from acid lime using GA3 @ 50 ppm in June + cycocel @ 1000 ppm in September + KNO_3 @ 2% in October. The spray of Ethrel @ 2ml/l before the start of bahar resulted in maximum defoliation in pomegranate *cv.* Bagwa under Maharashtrian conditions (Supe *et al*., 2013). Combination of GA_3 with shoot pruning 15 cm was most promising for yield improvement in lemon *cv.* Assam lemon (Mahesha *et al*., 2018). Firoz *et al.* (2021) reported use of cycocel @ 1500 ppm resulted in maximum fruit yield in hastha bahar in *Punica granatum cv.* Bhagwa. Whereas, under *cv.* Kandhari in agro-climatic conditions of Allahabad GA3 @ 75 ppm provides the best results for vegetative and flowering parameters (Phawa *et al*., 2017). Stern *et al*. (2014) reported that during 30 per cent of full bloom, the application of the gibberellin inhibitor uniconazole inhibited the fruit set of 'Bing' delicious cherry. This reduced manual thinning time by roughly 50% and crop load by 40% and there was also a significant shift to bigger fruit sizes (>26 mm), providing the crop load was not too low. Next year, no detrimental impacts on blooming or yield were identified. Mahalle *et al*. (2010) confirmed that two sprays of cycocel @ l000 ppm at an interval of one month before the onset of flowering in August and September for Hasta bahar flowering (*i.e.*, September and October) of acid lime resulted in maximum productivity in terms of the number of fruits per tree and weight of fruits per tree and this treatment also enhanced the fruit quality in respect to juice content, TSS, acidity, ascorbic acid content, peel and pomace percentage. Atay and Koyuncu (2016)

reported the efficiency in using GA_{4+7} as a foliar spray to reduce the alternate bearing effect in golden delicious apple grated on M_9 stock. The lower alternate bearing index resulted in controlled flowering for the current year and a better return bloom.

Shoot Bending

Bending promotes abundant blooming and fruiting in plants, resulting in higher yields. When a branch is bent, the wood stress increases and phloem development decreases. Consequently, photosynthetic byproducts move more slowly from bent branch shoots to other regions, sustaining an enhanced C: N ratio and inducing more flowering and fruit sets. Bending stimulated the development of latent reproductive buds. The bent branch produces more flowers and fruits than the straight branch (Jatt *et al*., 2020). Samant *et al.* (2016) reported branch bending in increased productivity, TSS, TSS/ acid ratio, and vitamin. C in the winter season guava cultivar "Lucknow-49. Similarly, enhanced yields were also reported by Nandi *et al*. (2017) on using branch bending in October.

Off-season fruit production

Fruit output varies by season in both tropical and temperate climates. Fruits are usually oversupplied during peak season, but there is no availability during the off-season. This situation is not economically viable since it creates dramatic changes in fruit prices. The price reduces considerably during the height of the season, while it is relatively expensive during the offseason or at the beginning and end of the season. Farmers and customers may profit from extending the fruiting season by starting the season earlier and postponing the conclusion of the harvesting season. The long-term supply-demand balance can be improved if some of the trees in the orchard are managed to blossom at various periods. This may be accomplished via advancements in off-season fruit-producing technologies. The induction and development of flowers is vital phase in fruit production. Flower forcing of fruit trees may be accomplished in a variety of methods, including modulation of air and soil temperature (Poerwanto *et al*., 2006), water stress (Liferdi *et al*., 2000), girdling (Rai *et al*., 2004), and treatment with plant growth regulators (Utama and Poerwanto, 2003).

Benefits of off season production

- Better quality of fruits
- Better market and high demand
- More profit
- Avoidance of some biotic stresses

Factors affecting off season fruiting

- Plant factors
- Genetics Factors
- Environmental factors
- Experience of grower
- Climatic conditions
- Orchard management'
- cultivars

Constrains of Off-season production

- Unseasonal rains
- Absence of strategic management practices
- Lack of quality planting material
- Use of pesticides
- No evaluation of fruiting behavior of exotic off season varieties

Use of poly tunnels and greenhouses as a structure for off season production

Poly-tunnels : These are passive solar structures that may be used to prolong the growing season by sheltering crops from potentially harmful weather conditions such as frost, temperature fluctuation, precipitation, wind, and excessive wetness (the significant reasons for planting or cultivation delays). These also minimize danger and improve harvest quality. Raspberries are ideally adapted for offseason production in greenhouses because they grow well at relatively moderate temperatures (20^0C) and are not impacted by photoperiodic length as necessary in strawberries (where we have to supplement the light for fruit production). The crop is mainly intended to be harvested from May through July. In comparison to the off-season and open-air production, the berries produced under protected conditions are larger, firmer, and free of abiotic and abiotic factors that disrupt fruit quality, and thus the fruit produced under protected conditions fetches a higher price than the fruit produced under open conditions.

Van *et al*. (2016) identified the lack of supply of strawberries during January till March under Belgium conditions. They advanced the fruiting by using supplemented lighting, and they covered the gap in the supply of strawberries from January to March. Read *et al.* (2021) filled the supply gap of strawberries in the market of the United Kingdom and reported improved yield and quality of offseason grown strawberries by use of supplemented lighting with LEDs and temperature control from December to March, which also enabled early harvest. Mizuno *et al*. (2022) produced early

cropping with double yield in October to mid-November using root zone cooling combined with short-day treatment in June bearing strawberries under super forcing culture under new root-zone Environmental control system (N.RECS). Lin *et al.* (2021) advanced bud break using defoliants such as lime Sulphur and urea improved the bud break from 42.6 to 76.8% and advanced the early season yield from 35-88%. This enabled the production of blackberries in the region where there is inadequate chilling. Tripathi *et al.* (2014) explored the production of offseason litchi in the Coorg and Waynad region as this region experiences the flowering during august- September and fruit are ready during December-January this is possible due to the difference in climatic weather of Coorg and Waynad, which allows the production of off-season litchi. Under Philippines climatic conditions, Pascua *et al.* (2013) evaluate the use of different types of light bulbs and foliar fertigation for the production of dragon fruit round the year. The light conditions modified the stimulus for florigen production and hence led to production of dragon fruit in the offseason and maintained the year supply of fruit. In order to maintain the round the year supply of cherry in north china, a model system was developed in china specifying the suitable cultivars and standardizing the climatic conditions led to the production of 6-7 ton/ha cherry during March to April end when there is no availability of cherry (Zhang *et al.*, 2014). Nakorn *et al.* (2014) used paclobutrazol and produced flowering 12 days earlier than trees under control. The paclobutrazol was also reported to increase flowering percentage and reduced shoot length, panicle length and leaf area. Manochai *et al.* (2005) also provided similar results on using $KClO_3$ as stem injection, and flowering was induced within 21 days. The foliar application was reported to be effective, but the flowering intensity was higher in the case of stem injection. Vinay and Chithiraichelvan (2015) observed the first flower on custard apple 73 days earlier than on plants under control when 50% pruning was performed with a Spray of 5 % urea. Application of paclobutrazol during 15th August induced earlier flowering similarly using 14.5 gm ai of paclobutrazol resulted in flowering four days earlier to control (Gohel *et al.*, 2021).

Maloba *et al.* (2017) induced off-season mango flowering by using KNO_3 @ 4%. The plant produced 50% flowering 50 days earlier than plants under control. Flowering percentage and fruit were also reported highest in same plants. Burondkar *et al.* (2013) produced fruiting in mango during January month using paclobutrazol on 15th May; however, under normal conditions, crop harvesting begins after the second fortnight of April. Using the MOST technique for mango fruit production resulted in earliness in flowering time for mango production and improvement in total fruit weight of mango (Husen *et al.*, 2021).

Conclusion and Future Thrusts

Various crop regulation mechanisms allow us to produce fruit beyond its typical growing season, providing farmers with higher returns for similar crops. However, different components of crop regulation and off-season fruit production must be thoroughly studied to have optimism in production mechanisms. In a nutshell, off-season fruit production is the next big thing, allowing consumers to have a wider variety of choices for consumption, as there is a need to diversify our food products for nutritional security in this pandemic time.

Future implications of the findings in fruit crop regulation and off-season production suggest a focus on advancing crop regulation techniques tailored to specific fruit crops and regional conditions. Research efforts could explore novel methods such as precision irrigation techniques and automated crop regulation systems to enhance fruit yield and quality while optimizing resource use. Climate-smart practices, including the use of climate-resilient cultivars and microclimate management techniques, hold promise for mitigating environmental impacts and ensuring consistent yields in the face of climate change. Additionally, advancements in off-season fruit production technologies, such as greenhouse automation and controlled environment agriculture, offer opportunities to extend fruiting seasons and meet year-round demand. Market analysis, consumer behavior studies and economic modeling are essential for identifying niche markets, value-added opportunities, and strategies for market penetration. Sustainable orchard management practices, including integrated pest management and soil health management are critical for long-term fruit production viability. Engaging stakeholders in participatory research initiatives and knowledge sharing platforms can accelerate innovation and adoption of best practices, empowering growers and enhancing fruit production sustainability.

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