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Crop Regulation in Guava: A review

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Abstract: Guava (*Psidium guajava* L.), commonly known as Apple of Tropics and subtropics. Amongst various tropical and sub-tropical fruit crops like guava grown in India, if left on its own, give several light crops of the variable quantities and qualities from the various flowering flushes throughout the year. Therefore, to obtain higher fruit yield during a particular period, bearing guava trees are given a resting period with artificial means so that the natural flowering tendency of the trees is altered. This can be achieved through root exposure and its pruning, shoot pruning, withholding irrigation water, deblossoming, chemicals/PGRs application and shoot bending. Regulated crops are desired to avoid glut in the market and also ensure the regular supply of fruits. The basic principle of crop regulation is to induce flowering and fruiting in desired season of the year that contribute to increased fruit yield, quality, profitability and sustainability of the environment by reducing the use of the frequency of the pesticides. Among various chemicals used NAA (600-800 ppm) and urea (10-15%) could be widely used in different agro-climatic conditions for crop regulation in guava.

Key words: Guava, crop regulation, deblossoming, root exposure, root and shoot pruning.

Guava (*Psidium guajava* L. 2n = 2x = 22) is one of the most delicious and popular fruit crops which belongs to the genus *Psidium* (Myrtaceae) grown commercially across the tropics and subtropics (Pathak and Ojha, 1993; Rodríguez *et al*., 2010; Mishra *et al*., 2019). India is the world's largest producer of guava, followed by Pakistan, Mexico, Brazil, Egypt, Thailand, Columbia and Indonesia (Pommer and Murkami, 2009). India produces 4253000 MT annually from an area of 276000 ha (NHB, 2020). It is commonly known as Apple of Tropics and subtropics and is valued for its adaptability to adverse edaphoclimatic conditions; prolific bearing and amenability to make value added products (Mishra *et al*., 2019). Guava fruits are exceptionally rich in vitamin C, potassium and phosphorus as well as antioxidants and dietary fibers (Jiménez-Escrig *et al*., 2001; Nimisha *et al*., 2013; Mishra *et al*. 2018). Guava fruits are either used fresh or predominantly processed into puree, paste, jam, jelly, nectar, syrup, ice-cream or juice. Various studies have demonstrated the ability of guava as an antioxidant, hepatoprotective, anti-allergy, antimicrobial, antigenotoxic, antiplasmodial, cytotoxic, antispasmodic, cardioactive, anticough, antidiabetic, anti-inflametary and antinociceptive activities supporting its traditional uses (Gutierrez *et al*., 2008; Shruthi *et al*., 2013; Mishra *et al*., 2022).

Amongst various tropical and sub-tropical fruit crops like guava grown in India, if left on its own, give several light crops of the variable quantities and qualities from the various flowering flushes throughout the year. Under natural conditions, guava produces flowers thrice in a year i.e. February-March (*Ambe Bahar*), June-July (*Mrig Bahar*) and October-November (*Hasth Bahar*) with the corresponding harvest during rainy, winter and spring season, respectively (Mishra *et al*., 2020). Owing to this, potential yield is not obtained during the desired period. Therefore, to obtain higher fruit yield during a particular period, it needs a resting period with artificial means so that the natural flowering tendency of the trees is altered. It can be achieved through root exposure and its pruning, shoot pruning (Tiwari *et al*., 1992; Thakre *et al*., 2016), withholding irrigation water (Mishra *et al*., 2020), deblossoming (Tiwari and Lal, 2007), chemicals/PGRs application (Maji *et al*., 2015), change in fertilizer schedule and shoot bending (Sarkar *et al*., 2005). However, the results of these experiments were not similar and the responses differed according to cultivars, tree conditions, soil types and agro-climatic conditions (Maji *et al*., 2015). Regulated crops are desired to avoid glut in the market and also

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Table 1. Flowering period of guava in different parts of India

Region/state	Flowering period	Reference
West Bengal, Eastern India	April-May and Sept.-October	Mitra, 1983; Singh, 1995
Punjab, North India	April-May and August-Sept.	Gupta and Nijjar, 1978, Singh, 1995
Maharashtra, Tamil Nadu, Southern and Western India	April-May, August-Sept. and October	Singh, 1995

ensure the regular supply of fruits (Mishra *et al*., 2020). The choice of *bahar* at a particular location is determined by prevailing production constraints like availability of irrigation water, quality of produce, market demand and extent of damage by insect-pests and diseases (Lal *et al*., 2017). The basic principle of crop regulation is to induce flowering and fruiting in desired season of the year that contribute to increased fruit yield, quality, profitability and sustainability of the environment by reducing the use of the frequency of the pesticides (Thakre *et al*., 2016; Lal *et al*., 2017; Mishra *et al*., 2020).

Present Status and Gap in Present System

Crop regulation in different fruit crops is about identifying, selecting, implementing and monitoring methods to control the yield and quality. It is planned and executed in such a way that it should not have negative impact on people, the environment or the financial bottom line. Different methods of crop regulation have been successfully demonstrated for improving the yield and fruit quality of guava in India (Lal *et al*., 2017) and other parts of the world (Atawia *et al*., 2017). Water stress seems to be the major flower-inducing signal under tropical conditions (Mishra *et al*., 2020). Regulation of flowering in tropical fruit crops in relation to the effect of the environment, interactions with vegetative growth, the roles of PGRs and carbohydrates and recent advances in molecular biology are also important (Wilkie *et al*., 2008).

Fruit production is seasonal activity and during the peak season price drops sharply owing to the glut in the market. At the same time in multiple flushing species like guava, desired yield and quality is not obtained during the peak demand period in the market. This condition is not economically sustainable. Therefore, to obtain higher fruit yield during a particular period, these fruit crops are given a resting period with artificial means so that the natural flowering tendency of the trees is altered. Various crop regulation methods in different agro-climatic conditions have been standardized for guava in India (Lal *et al*., 2017). However, manipulation for flower forcing and fruit setting has not yet been fully commercialized.

Approaches for Crop Regulation in Guava

Guava is the fifth most important fruit crop which is successfully grown over a wide range of soil and climatic conditions. It is available at reasonable price and known for its rich nutraceutical values and, named as apple of tropics and super fruit (Maji *et al*., 2015). In general, guava flowers twice in a year, i.e., in March-April (*Ambe bahar*) and June-July (Mrig bahar), of which fruits ripen in rainy and winter season, respectively (Table 1). However, in central and south part of India, there is a third crop with flowers appearing in October (*Hastha bahar*), of which fruits ripen in the month of March. This pattern of flowering and fruiting is not desirable for commercial exploitation (Mishra *et al*., 2020). Moreover, the fruits of *Ambe bahar* which are harvested during the months of July-September are insipid, watery, poor in quality and heavily infested with fruit fly resulting in significant loss to most of the guava growers (Thakre *et al*., 2016). The winter season fruits are superior in quality, free from pests which fetch high monetary returns (Singh *et al,* 2000). Obviously, regulation of crop will help to overcome such problems to a great extent by giving various flower and fruit thinning treatments during summer months.

Withholding of irrigation water

In this approach, watering of trees withheld from February to mid of May which results in the shedding of flowers and trees go to a rest period during which accumulation of food materials takes place in branches (Singh, 1995; Sachin *et al*., 2015). This method is suitable for light sandy soils; however, in heavy soils or soils of *Tarai* region, this method was not found

useful (Tiwari and Lal, 2000). Cheema *et al*. (1954) advocated withholding of water and removal of soil from the upper roots by June 10 followed by covering tree basin with soil and manure mixture followed by irrigation to get winter crop in Maharashtra. The trees thus treated produce profuse shoot growth followed by heavy flowering leading to enhanced yield in winter season.

Singh *et. al.* (1997) studied the effect of soil-moisture stress on relative water content, proline accumulation in leaf, fruiting behavior and fruit quality was in 'Allahabad Safeda' and 'Sardar' guava. Stress was exerted on trees by withholding water from January to June, and the non-stressed control trees were watered at an interval of 10-15 days, depending on the evaporation. The abscission of flowers was noticed when relative water content reached 60.20% in 'Allahabad Safeda' and 53.40% in 'Sardar' guava. A trend was also noticed in the quantity of leaf proline according to the degree of water stress. The metabolic activity in the plants was maintained better even at low RWC in 'Sardar' than 'Allahabad Safeda'. 'Sardar' appeared more tolerant than 'Allahabad Safeda'. Water-deficient trees had significantly lower yield during rainy season in both the varieties. However, 'Allahabad Safeda' responded more to soil moisture stress for regulation of flower to harvest and better fruit yield during winter season than 'Sardar'. In 'Sardar' in addition to soil-moisutre stress a chemical that can inhibit the growth may also be essential to regulate cropping.

Root exposure and root pruning

In this method, upper soil around the tree trunk (7-10 cm) in a radius of 40-60 cm removed so that roots are exposed to the sun which results in reduced moisture supply to the top, therefore, the leaves begin to shed the leaves and tree goes to a rest period. After about 3-4 weeks the exposed roots again covered with soil and manure mixture followed by watering (Singh, 1995, Lal *et al*., 2017). Consequently, trees put forth new growth, profuse flowering and fruiting. However, in light sandy and shallow soils, exposure of root is not required as withholding of irrigation water for 2-3 weeks is sufficient for leaf wilting and shedding. Water stress can be induced through root exposure and pruning of minute roots to suppress the rainy season crop and to get a good winter crop (Cheema *et al*., 1954, Sachin *et al*., 2015, Suresh *et al*., 2016).

Shoot pruning

In guava flowers are always borne on newly emerging vegetative shoots therefore, shoot pruning have been reported to be highly successful in guava irrespective of the time of year (Thakre *et al*., 2016). This makes guava unique, that it can be pruned for regulating the crop (Lotter, 1990). Shoot pruning is helpful in reducing the tree size and improving the fruit quality (Singh and Bal, 2006). The beneficial effect of pruning on yield and fruit quality of guava is reported by various workers (Bajpai *et al*., 1973; Lal, 1983; Jadhav *et al*., 1998; Lal *et al*., 2000; Singh and Singh, 2001; Dhaliwal and Singh, 2004; Kumar and Mishra, 2010). One leaf pair shoot pruning of current season's growth of spring flush in the first week of May recorded the maximum yield (Tiwari and Lal, 2007) in Tarai region of Uttarakhand and quality (Sharma *et al*., 2013) during winter season. Similar results of shoot pruning were obtained in high density plantings of guava (Chandra and Govind, 1995; Thakre *et al*., 2013; Pratibha and Lal, 2013; Thakre *et al*., 2016; Joshi, *et al*., 2016). Pruning was found to modify the production curve of guava (Quijada *et al*., 1999). Salah (2005) recorded the highest bud emergence in guava trees by using severe and moderate pruning. The time and intensity of pruning affected guava cv. Paluma tree sprout and yield (Serrano *et al*., 2008a). Moreover, reported that the light pruning increased the number of productive branches and number of fruits per branch in guava cv. Paluma (Serrano *et al*. 2008b). Similarly, pruning guava plants at a 20 cm pruning level in early May was the most effective management to reduce yield in the rainy season and to enhance yield and quality in the winter season in Nepal (Adhikari and Kandel, 2015). Contrary to this, 10 cm apical pruning in May month resulted in higher yield and fruit quality in Cairo, Egypt (Sahar and Hameed, 2014). Prakash *et al.* (2012) also conducted an experiment to improve the fruit yield and quality of monsoon flushed guava crop by regulating flowering of spring-flushed crop using varying shoot pruning intensities (25 to 75%) under subtropical condition of Western Uttar Pradesh. Summer pruning of spring flushed bearing shoot of current season

was found significantly effective in increasing the production of superior quality fruits in winter guava. With the increase in summer pruning severity, yield and quality of winter guava was improved significantly up to 33% pruning intensity. Hence, moderate pruning of bearing shoot of current season's growth just before bud opening in summer was significantly most effective in improving the production of monsoon flushed crop and fruit quality of spring and monsoon flushed crops in guava. This might be due to the fact that the plants accumulated food during rainy season which might have been got utilized for the development of winter season fruits (Chandra and Govind, 1995). Pruning results in greater penetration of photosynthetic photon flux in canopies of pruned trees than in unpruned trees during May and June which significantly increased the quantum of fruit yield harvestable during December and January by May pruning. Therefore, it can be concluded that shifting of rainy season crop to winter months in guava cultivars with the help of pruning in May is found economically efficient (Singh *et al*., 2001).

Deblossoming

Various types of chemicals and PGRs have been used for deblossoming of rainy season crop which subsequently increased the winter season crop (Lal *et al*., 2017). Manual deblossoming on a commercial scale is economically not viable (Singh *et al*., 2002); however, in contrast to this Das *et al.* (2007) found it economically profitable when 50% of rainy season crop is removed manually. Rathore (1975) noted 96% deblossoming with 100 ppm NAA in guava while 200 ppm NAA was effective for guava cv. L-49 in rainfed plateau conditions of eastern India (Das *et al*., 2007). On the other hand, Chundawat *et al*. (1975) reported 82% deblossoming with 400 ppm NAA spray. However, complete deblossoming was recorded by Pandey *et al*. (1980) with 400 ppm of NAA while More *et al*. (2016) recorded maximum flower drop (80.40%) and fruitlet drop (73.54%) during rainy season crop and higher yield in winter season crop with 800 ppm NAA. Application of NAA (800 ppm) has been found useful to get a good winter crop by several other workers (Singh and Reddy, 1997). Flower thinning by using NAD (Kumar and Hoda, 1977; Mitra *et al*., 1982; Maji *et al*., 2015), 2,4-D (Kumar and Hoda, 1977; Das *et al*., 2007), potassium iodide (Narayan *et al*., 1999; Singh *et al*., 1996; Sachin *et al*., 2015) and ethephon (Singh *et al*., 1996; Singh *et al*., 2000) have been tried with varying degree of success.

The maximum deblossoming has been observed with 20% urea spray in guava (Dwivedi *et al*., 1990; Singh *et al*., 1996 and Singh *et al*., 2002). Whereas, Singh *et al.* (1994) and Choudhary *et al*. (1997) found 15% urea most effective for deblossoming of rainy season guava crop. Singh and Singh (1994) reported complete deblossoming with double spray of urea (15%) in guava to regulate the crop. However, single application of urea (25-30%) virtually eliminated all the summer flower and flower buds within 12 days and drastically reduced the rainy season yield. Among the treatments, trees which received single treatment with 25% urea produced higher yield in cv. Sardar, while in cv. Allahabad Safeda, two applications of urea (10%) had the highest fruit yield closely followed by single treatment with 20% urea (Singh *et al*., 2002). Shigeura *et al*. (1975) in Hawaii and Chapman *et al*. (1979) in Australia used urea sprays (25%) as a defoliant on guava to change the yield pattern from scattered bearing to a concentrated peak harvest during the desired period. Addicot (1964) reported that most defoliants have no direct effect on the abscission zone, however, induces abscission by way of leaf injury which sets in motion the chain of events leading to leaf fall. This abscission may be caused by the direct effects of urea or by NH_4^+ released by urease (Singh *et al*., 2002). Chemical treated trees had positive effect on most fruit chemical properties as compared to the control (Atawia *et al*., 2017).

Shoot bending

Yield and quality of a particular variety may be governed by its growth habit, as guava trees in which shoots grow erect bear poorly (Singh, 1995). In this context, branch bending and pruning could be of great use. The cultural practices are known to induce the lateral shoot production by breaking the apical dominance and activating the latent buds present on the branch (Samant *et al*., 2016) which bears flowers and fruits. Branch bending treatment which was imposed in the month of May contains the growth (56.91 cm) of newly emerged shoots as compare to control (68.10 cm). The same

treatment was found very effective in inducing flowering (46.27%) and recorded the highest yield with improved fruit quality parameters (Samant *et al*., 2016). Shoot bending is one of the ways to produce better quality fruits in the offseason (Sarker *et al*., 2005, Mamun *et al*., 2012). In case of bending of branch, wood tension of branch is increased and phloem formation decreased. As a result photosynthetic product pass slowly from the shoots of bent branch as to the other parts, maintaining increased C:N ratio and induce more flowering and fruit set (Mamun *et al*., 2012).

Potential Benefits and Future Research Need of Crop Regulation

Cultural and hormonal manipulations for flower induction and fruit setting have been adopted commercially guava for various reasons. These are to regulate a uniform and good quality fruits (Lal *et al*., 2017). In addition to this to extended harvesting season (Mishra *et al*., 2008), reduce the attack of insect-pest and diseases (Khan *et al*., 2011; Lal *et al*., 2017) and increase the nutritional quality, profitability and environmental sustainability (Singh *et al*., 2000; Das *et al*., 2007; Maji *et al*., 2015; Lal *et al*., 2017). Fruit production is season bound activity which leads glut in the market therefore fetches poor prices and sometime also leads higher fruit spoilage too. This seasonal supply is also limited to few days to few months. Thus, through adoption of various flower regulating techniques at commercial scale, harvesting season can be extended. Thus focus of research should be given in this direction so that fruit availability could be increased during the lean periods in India. Physiology and molecular biology of crop regulation is extensively studied in many tropical fruit crops, however, attention in this direction needs to be given for guava for better management and understanding.

Conclusion

Under natural conditions, guava flowers thrice in a year i.e. February-March, June-July and October-November with the corresponding harvest during rainy, winter and spring season, respectively due to which potential yield is not obtained during the desired period. Therefore, to obtain higher fruit yield during a particular period, bearing guava trees are given a resting period with artificial means so that the natural flowering tendency of the trees is altered. It can be achieved through root exposure and its pruning, shoot pruning, withholding irrigation water, deblossoming, chemicals/ PGRs application and shoot bending. However, the results of these experiments were not similar and the responses differed according to cultivars, tree conditions, soil types and agro-climatic conditions. Regulated crops are desired to avoid glut in the market and also ensure the regular supply of fruits. The choice of *bahar* at a particular location is determined by prevailing production constraints like availability of irrigation water, quality of produce, market demand and extent of damage by insect-pests and diseases. The basic principle of crop regulation is to induce flowering and fruiting in desired season of the year that contribute to increased fruit yield, quality, profitability and sustainability of the environment by reducing the use of the frequency of the pesticides. The investigations on crop regulation showed that shoot pruning and application of various chemicals were effective to regulate flowering in guava by deblossoming of summer flowers and to produce fruits in winter. Among various chemicals used NAA (600-800 ppm) and urea (10-15%) could be widely used in different agro-climatic conditions for crop regulation in guava.

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