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Systems of crop regulation in guava and their assessment

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Abstract
The guava (*Psidium guajava* L.) is a fruit that has the potential to be profitable as well as being nutrient-rich. It has two seasons of blooming. However, in terms of production and quality, both season crops differ. The basic principle of crop regulation is based on the fact that guava flowers appear on new tender, vigorous on developing vegetative growth and the plant is compelled to be dormant and after the resumption, it (tree) produces bumper flowers and results in a heavy yield of better quality. Above all, such a cropping pattern results in increased grower returns while keeping control over consistent, high-quality fruit production. On the contrary, continuous blooming would result in lower yield along with extra watch and ward and marketing costs. Henceforth various techniques are used to regulate guava crops including withholding irrigation, flower bud thinning or removal, pruning level technique. All these techniques help to lower fruit set during the rainy season along with incline production in winter season. This paper includes all previous efforts concerning regulations/recommendations to date and future perspectives.

Keywords: Crop regulation, guava, DE blossoming, PGR, pruning, water stress and other techniques

1. Introduction
Guava (*Psidium guajava* L.), a member of the family- Myrtaceae, is a tropical fruit, native to Mexico (America). Countries like India, China and Thailand are the leading producers of guava. According to NHB (2023) [41], the area under this crop is 359 thousand hectares with a production of 5.59 million metric tons (Shankar *et al.*, 2023) [52]. It is commercially cultivated in sub-tropical regions of the Indian subcontinent (Uttar Pradesh, Punjab, and Haryana) with average productivity of 15.9 mt/ha. Uttar Pradesh (with share–21.78%) is the principal state in guava production followed by MP (17.20%) and Bihar (9.62%). Common varieties of guava cultivation in India are Allahabad Safeda, L-49 (Sardar), Arka Mridula, Pant Prabhat, Lalit, Khaja (Bengal Safeda, Dhareedar, Chittidar and Harija. Along with this some hybrid varieties also exist like Safed Jam, Arka Amulya and Kohir Safeda. However, the best quality guava is produced in Uttar Pradesh (Majeed *et al.*, 2024) [32]. Minimum maintenance and assured cultivation make guava a low-cost production crop and popular crop. Moreover, fruit is very cheap (cost wise) and easily available at reasonable prices. The notable ingredients of guava plants are tannins, vitamins, sesquiterpene alcohols, triterpenoid acids, phenolic compounds including essential oils (Olatunde *et al.*, 2024) [42]. Vitamin C content of guava is five times that of citrus fruit and ranges between 150 to 200 mg/100 g of pulp. Comparatively higher production results from rainy season but fruits are of inferior quality while quality is far better in case of winter crop, no fruit infestation, as a result, fetches a higher price in the market than rainy season produce (Gupta *et al.*, 2024) [17]. Groh *et al.*, (2020) [16] also admitted that winter season cropshave low yield but long-lasting storage life. A significant part of the produce is lost due to improper post-harvest operations and perishable nature, there is a vast gap between production and accessibility (Tarekegn and Kelem *et al.*, 2022) [60]. Due to all these problems, crop regulation must be practised and worked out. So, under the presentscenario, it is suggested to take only a single crop that should be bumper with good quality. This necessitates the management of de-blossoming to obtain the desirable crop, by various approaches like withholding irrigation, flower thinning by using chemicals or manually including pruning techniques.

In this review paper, earlier carried out work by various scientists on crop regulation and recommendation in this concern, is compiled under different subheads.

2. Need for Crop Regulation

Improvement in cropping patterns and low income of the farmer may be formulated/enhanced by compiling various advanced cropping technologies, by bridging the productivity gap, precision farming and intensification in cropping intensity wasteland management and resourceful land-use scheduling along with divergence towards high worth crops and upgrading marketing system. Stout *et al.*, (2023) [57] also stressed that there is utmost requirement to shift in farmers' insight from production to productivity and cost-effective cultivation. To achieve various efficient and scientific research concepts like high-density planting etc. there is a need to follow crop regulation. Winter season guavas are obtainable from the second fortnight of October to the first fortnight of January. Productionof the winter season results in an improved quality crop and fetches a higher price in the market. Moreover, it has also strengthened the statement that there is no fruit fly infestation and procures higherpricesas compared to the rainy season production (Mastrangelo *et al.*, 2021) [33]. Above all, winter seasoncropslead to less production. Quality and returns of the crop are decided by-

1. The flowering is bumper in the summer season due to humid climatic conditions resulting in high yield during the rainy season. High temperature and moisture during fruit harvesting, reduction in harvesting period causes surplus production. The market glut of guava leads to low monetary returns and less demand in the market.
2. Fruits of the rainy season crop are inferior in quality and infested by many insect pests (Sharma *et al.*, 2021) [53].

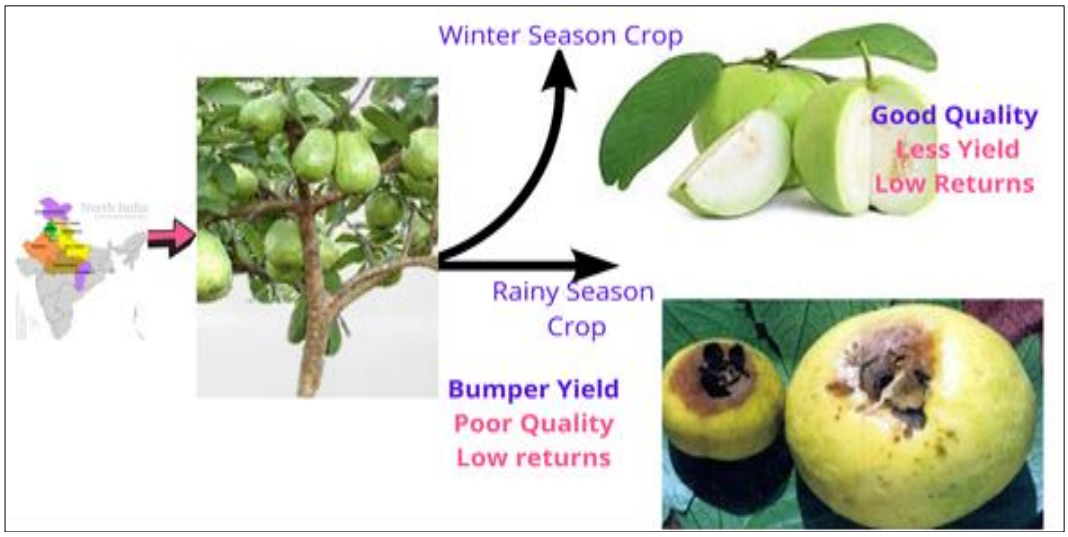


Fig 1: Two crops of guava in India and quality

Infestation of insect pests, especially fruit flies, is a serious problem during the rainy season. Various workers have given the same statements that fruits produced in the rainy season are harshly condemned by insects like fruit flies (Holmes *et al.*, 2023) [19]. Due to severe infestation of fruit flies, the fruits become unfit for human consumption as they contain maggots (Fig. 1). Thus, it is suggested to retain only winter season crop flowers and rainy season flowering should be rejected (Patel *et al.*, 2021) [43].

3. Significance of crop regulation

As mentioned above, guava bears a poor-quality crop in the rainy season which suffers from many stresses (biotic and abiotic) as compared to the winter season crop. Guava crop of winter season (Mrig Bahar) is of improved quality as it is free from maggots, insects and pests and fetch good prices in the market. The choice of 'bahar' is mostly decided by the existing production restrictions, such as the accessibility of irrigation facility, product worth, incidence and severity of disease and pest damage, and a number of market deliberations (Sangamnere *et al.*, 2023) [47]. Chary *et al.*, (2023) [9] revealed that the Deccan part of the country has mild climate and crop regulation is a favorable practice in that area (South India) to achieve blossoming in the desired season.

Table 1: Crops of guava in India, their flowering and fruiting time

Bahar	Flowering season	Fruiting or Ripening period
Ambe Bahar	February-March	July-August
Mrig Bahar	June-July	Nov-December
Hasta Bahar	October-November	March-April

***Source*:** Singh *et al.*, (2018) [54].

4. Crop regulation objective in Guava

The foremost objective of crop regulation is to force/compel guava trees to take rest or to be dormant and produce heavy blossoms and fruits out of two or three flushes (Table 1) This leads to maximization of grower' profit. Crop regulation also lowers the cost of cultivation as poor-quality crops which fetch lower pricesin the marketare avoided along with other related expenses like watch and ward, market and transport expenses (Ibn-Mohammed *et al.*, 2021) [21]. According to this concept, the resting period of the guava tree is also decided. Normally we choose the best time/flush of bear out of many flushes/flower seasons. To achieve these objectives, various techniques like deblossming, root exposure, pruning (root and shoot), withholding irrigation water along with use of various chemicals and plant growth regulators, are used (Fig.1). Many aspects are considered for selection of flowering and fruiting season like extent of the damage by the various

pests like fruit fly, their life cycle etc., quality production and other market factors. Kumar *et al.,* (2021) [27] also advocated that the concept of crop regulation should be achieved but not at the cost of the environment or the financial aspect.

5. Crop regulation principles

According to (Sathiah *et al.,* 2021) [49], the basic principle of guava crop regulation is to manipulate the flowering and fruiting behavior of guava in desired time that enhances yield with quality fruit, cost-effectiveness and conservation of the environment by lessening the frequent use of the insecticides. According to principles of crop regulation, different aspects like identification, selection, implementation and governing methods are used to obtain improved quality and economical yield. Above all, sustainability fact is also emphasized that to accomplish this concept, there should be harmful effects on the environment or the financial bottom line (Kumar *et al.,* 2021) [27].

6. Crop regulation strategies

To get the winter season crop (only) it is obligatory to regulate the flowering pattern. The feasible solution to this problem would be to abolish the rainy season crop i.e., flowering (Liu Beckie *et al.,* 2023) [30]. Various techniques to avoid monsoon crop through hand deblossoming, use of chemicals at blossoming stage and pre-bloom stages which correspondingly encourage good crop, are available as earlier works

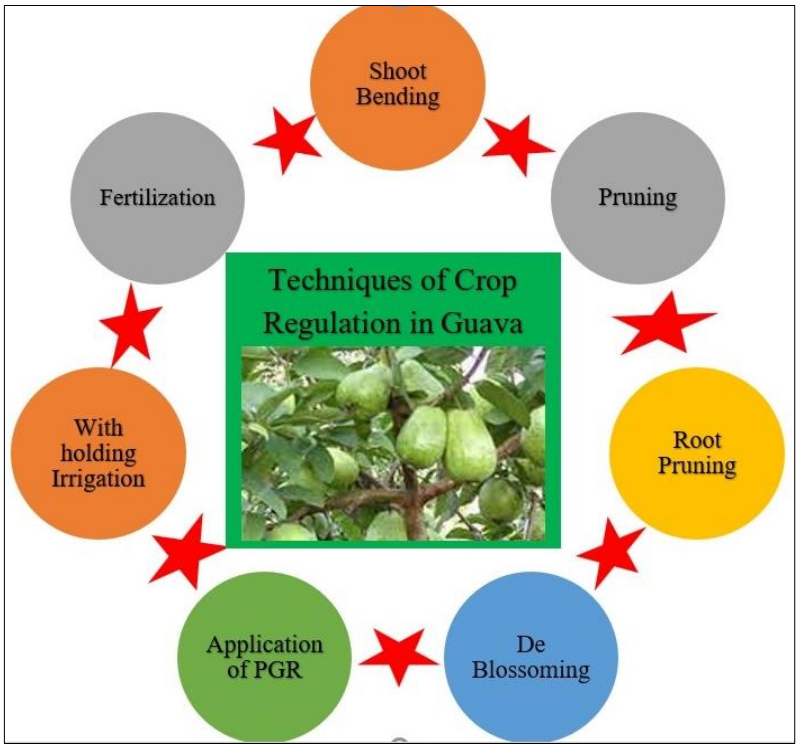


Fig 2: Various techniques of crop regulation

To take the desirable season crop and avoid the undesirable, various practices like withholding of irrigation, shoot pruning, flower bud thinning and the application of diverse chemicals have been recommended (Jat *et al.,* 2023) [23].

6.1 Withholding irrigation

Normally withholding irrigation results in dropping of leaves, flowers and ultimately the guava tree goes into dormant state. According to this approach, the tree basin is excavated and left as such for some period (Thind and Mahal, 2021) [62]. After that fertilizer and water are applied to the excavated trench. The tree starts to blossom heavily and these flowers result in fruiting after about 3 weeks, during the winter month. This kind of approach concerning water stress depends upon the prevalent conditions. (Melrose and Normandeau, 2021) [34] also mentioned that to accomplish crop regulation, irrigation is withheld after harvesting during April-May in Indian plains. This practice leads to shedding of leaves, flowers and the plant goes into dormancy. In June, the irrigation is again done, which results in profuse flowering after one month and the fruits are matured in the winter season.

6.2 Fertilization

Kowalska *et al.,* (2023) [26] revealed that application of fertilizers in June-July-August encourages growth and flowering for a better winter season crop and it is the best approach. Changing the fertilizer schedule in guava crops during winter season (April-May to June) will result in more vegetative growth that consequently inclines the winter season production. Kumar *et al.,* (2021) [27] also advocated that various manures and fertilizers should be applied 15 days before bending of branches (if experienced) and then again applied at pea stage of fruit development and lastly it should be followed by irrigation.

6.3 Shoot bending

In this technique, dormant reproductive buds are forced to induce growth. Bending practice induces abundant flowering and fetches good price (Nanda *et al.,* 2023) [39] and helps in the regulation of flowering (Srivastava *et al.,* 2022) [56]. Kumar *et al.,* (2021) [27] obtained more flowers per plant when shoot bending treatment was practiced during on-season (312.33) while during the off-season it lowered flowering (111.33). Samant and Kishore, (2021) [46] reported

similar results that shoot bending practice results in higher number of fruits irrespective of season. Under West Bengal conditions, most farmers/growers choose winter season guava and they adopt shoot bending technique for regulation of flowering in August-September (GMS *et al.*, 2022) [15].
Significant results regarding the effect of bending technique in guava were described by (Tamang *et al.*, 2021) [58]. It is supposed that bending of shoots improves blossoming by shifting hormonal balance in branches and especially the level of endogenous abscisic acid in tip of the shoot as well as in the roots that were absolutely correlated with bending of the branch and was considerably noticeably advanced than control one. It was reported that bending of shoots in October month is effective in increasing shoot length and yield followed by bending of shoots in June (Atal and Mitra 2023) [6].

6.4 Hand thinning

Hossain *et al.,* (2020) [20] revealed that thinning results in size-lessening declination of the rainy season guava crop along with some other practices like prevention of irrigation etc. Some scientists have revealed that this approach should be followed by twice the spray of urea. First spray of urea (@15%) at 50% flowering and second after 10 days of first spray along with hand deblossoming and ¾ current shoot pruning (30th May) for Sardar guava (Ranpise *et al.*, 2022) [44]. Adoption of hand thinning practices in the rainy season crop at small scale in kitchen gardens is very effective only when it is performed at early age of the plant. In large commercial orchards, the practice of hand thinning becomes very cumbersome and laborious.

6.5 Pruning

Pruning helps in two ways, firstly to regulate crop (Avelino *et al.*, 2023) [7] and secondly to manage high density (Chun *et al.*, 2023) [10]. Shoot pruning is helpful in reduction of tree size along with improvement in fruit quality and offers a good opportunity to enhance the plant number per unit area (Anthony *et al.*, 2021) [4]. 50 percent shoot pruning of guava cv. L-49 (Sardar) in May, yielded improved fruit yield in winter guava crop (Dutta, 2022) [12]. Application of different growth regulators like ethephon at 500 and 1000 ppm, paclobutrazol and pruning practices in guava cv. Allahabad Safeda trees during the rainy season led to better crop regulation in terms of fruit yield in summer season followed by heading back to current season shoots which resulted in improved fruit yield during winter season crop (Santhoshkumar *et al.*, 2022) [48]. Nautiyal *et al.*, (2023) [40] recorded maximum yield with one leaf pair pruning in winter. It was noted that total yield during both cropping seasons was the highest in control but production of good quality fruit during winter season resulted in higher yield as compared to control. Kamusiime *et al.*, (2023) [24] also advocated that maximum number of fruits in winter season crop can be obtained from plantations in which three-fourths of shoot was pruned in May. Profit was also maximum in one leaf pair pruning technique along with holding in the rainy season crop (Kumar *et al.*, 2021) [27]. Pruning has a rejuvenating impact on old trees due to enhanced light interception, improved nutrient and water supply, photosynthetic rate and better-quality yields and reduced canopy (Ali, 2023) [3]. Srivastava*et al.*, (2022) [56] also advocated that for crop regulation purpose, trees should be pruned during May which results in improvement yield in winter season.

6.6 Root pruning method

This method involves 7-10 cm soil from roots zonein a circular manner along with withholding irrigation for 1-2 months before flowering. Due to water stress and evaporation (water) from roots is enhanced and leaves show signs of wilting and shedding occurs. Before the bahar season (approximately one month ago), filling of trench with soil, FYM and irrigation are applied. Subsequently, plants put forth new vegetative growth and profuse flowering is the result. But this approach is not applicable for light soils as simple withholding of irrigation for 2-3 weeks is sufficient for this purpose. But Lobato *et al.*, (2021) [13] considered that root pruning has harmful effects on the permanency of trees. Removal of small roots is also practiced in some parts of Maharashtra but along with suppression of irrigation, to permit the foliage to shed (Mamun *et al.*, 2022) [2]. But this practice of root pruning is not recommended/followed in Uttar Pradesh as it enforces moisture stress and ultimately results in leaf drop and growth termination of trees during the period of undesirable bahar (Kumar *et al.*, 2021) [27].

6.7 DE blossoming

Several chemicals help to remove flowering of guava and consequently improve the rest of the crop (Kumar *et al.*, 2021) [27]. Various authors described that diverse chemicals compounds (4, 6-dinitro-o-cresol, DNOC, 0.5% potassium iodide, 10, 15 and 20% urea or NAA @ 600 ppm, NAD, 2, 4-D, carbaryl and ethrel) can be used to remove flowers of the rainy season crop during May and consequently the yield of winter season guava is increased (Kumar *et al.*, 2021) [27]. In a research experiment, Ikhlaq *et al.*, (2022) [22] also noted substantial de-blooming in the summer guava crop. Deblossoming of the rainy guava crop by application NAA @ 800 ppm will help to increase yield of the winter crop in cv. Sardar Guava (Mishra and Singh 2021) [37].

6.8 Application of PGRs/ Chemical

Paclobutrazol has been reported to induce early flowering in guava (Moreno *et al.*, 2022) [45]. It has been reported that successive applications of paclobutrazol in September, October and December advanced flowering period. But application of paclobutrazol during July gave much better results under Nepal conditions. Gill *et al.*, (2023) [14] also described that application of GA_3 50 ppm during June + cycocel 1000 ppm (September) + KNO_3 2% (October) delayed flowering by two months.

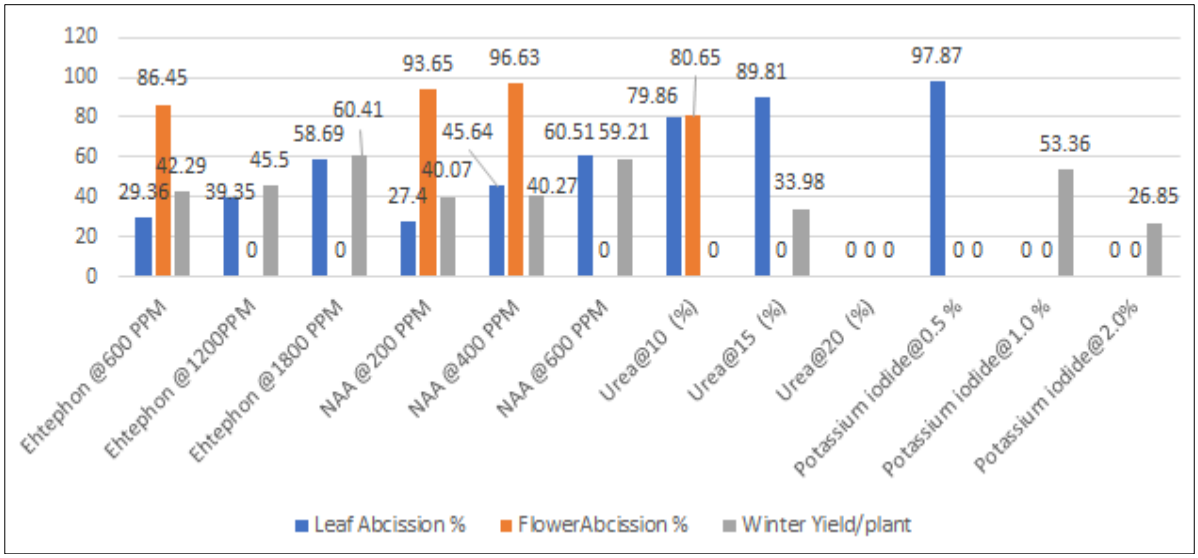


Fig 3: Effect of different chemicals on leaf abscission and fruit yield/plant during winter seasons in guava

Tarai *et al.*, (2022) [59] revealed that summer deblossming with application of NAD @ 60 ppm is the best strategy for crop regulation, followed by NAA @ 500 ppm and NAD @ 40 ppm. Above all, these applications aim to get quality fruits with handsome revenue.

7. Evaluation

7.1 Effect on leaf abscission

Kumar *et al.*, (2021) [28] experimented on Allahabad Safeda and found that potassium iodide (@0.5, 1.0, 2.0%), urea @ (15 and 20%), ethephon (1800 ppm) and NAA (600 ppm), application resulted in severe leaf and flower abscission (fig. 3). It was proved that application of urea @ 25% causes considerable leaf removal along with early cropping in guava crops (Singh *et al.*, 2022) [55].

7.2 Fruit set

For guava crop regulation in preferred season, it is important to minimize fruit set during the rainy season by using different chemicals and techniques (Lian *et al.*, 2024) [29]. But Ikhlaq *et al.*, (2022) [22] noted that fruit set was maximum with the application of 10 and 15% urea in winter season. Analogous results were recorded by Zahira *et al.*, (2023) [67] with 10% urea.

7.3 Fruit size

The size of guava fruits can be improved by the use of several thinning chemical agents (Haque *et al.*, 2022) [18]. However, Momtaz *et al.*, (2023) [38] observed the size improvement with certain chemicals like urea, NAA, ethephon, and potassium iodide treatments. Mirbod *et al.*, (2023) [36] revealed that bending of branches in May and June led to improved fruit size (length and diameter) fruit weight.

7.4 Fruit weight

Mishra *et al.*, (2021) [37] obtained improved average fruit weight in case of cv. Sardar guava when urea, NAA, potassium iodide, and ethephon were applied and the highest fruit weight was observed with 10% urea spray. However, Kaur *et al.*, (2024) [25] obtained similar results with NAA 100 ppm. WIDYASTUTI *et al.*, (2022) [64] stated that bending in May and June led to improved fruit weight of guava.

7.5 Fruit number

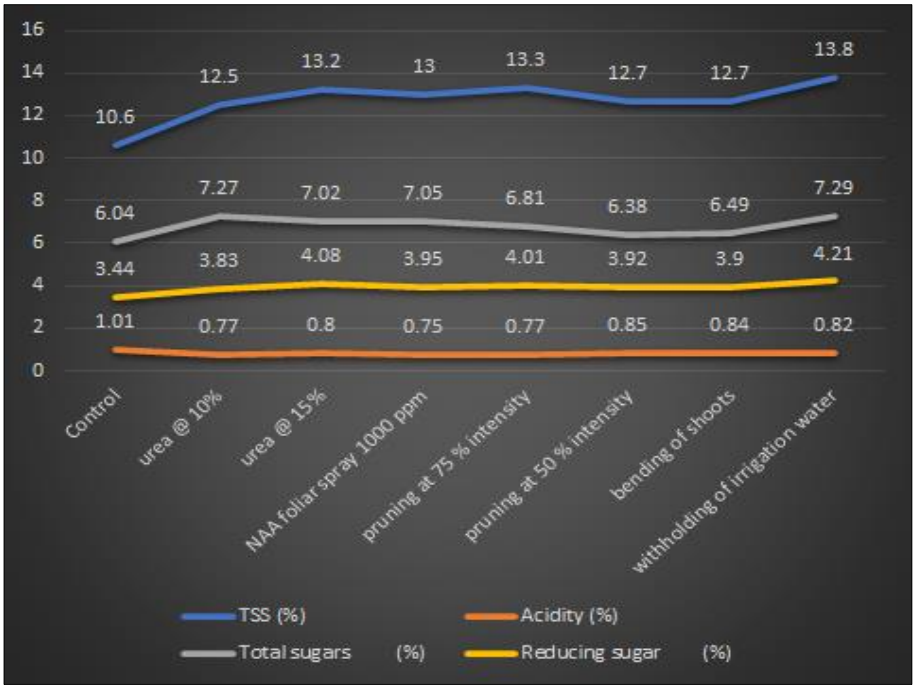
Lian *et al.*, (2024) [29] also recorded maximum fruits (number) in lightly pruned trees followed by mild and severely pruned trees in the rainy season but on the other hand, heavily pruned plants gave much lower fruits in the rainy season cv. Allahabad Safeda. Arredondo *et al.*, (2022) [5] perceived that with increase in pruning intensity (with full shoot pruning) fruit number is decreased while there was very less or no fruiting during the rainy season. Comparable results were submitted by (Chander *et al.*, 2022) [8].

7.6 Fruit yield: Yield is an ultimate factor that governs the failure and success of particular technology for farmers. Kumar *et al.*, (2021) [27] submitted that application of various chemicals like KI, urea NAA and ethephon did not demonstrate any encouraging results for enhancing the fruit yield. Viljoen *et al.*, (2021) [63] observed no direct linkage between flower abscission and yield during winter season. Menzel *et al.*, (2022) [35] stated that dissimilar defoliation treatments along with deblossoming levels in winter season and summer crops did not influence the yield. Still, defoliation and deblossoming had advanced the crops by 30 days or so. Singh *et al.*, (2022) [55] described that pruning of one leaf pair declined fruit number per guava tree in the rainy season and improved yield in winter season. Highest fruit yield during off-season was recorded in shoot bending treatment (Tamang *et al.*, 2021) [58].

8. Quality characters

8.1 Sugars

Kumar *et al.*, (2021) [27] recorded improved sugar/acid ratio with various chemicals like 2, 4-D, DNOC, NAA and urea during both seasons (winter and rainy). Correspondingly, it was reported that application of various chemicals like urea, ethephon and NAA had an important influence on total sugar of guava during winter and rainy seasons (Dutta, 2022) [12]. GMS *et al.*, (2022) [15] described that shoot bending treatmentin May improved the quality of guava fruits in terms of total sugars and reduced sugars. Various scientists revealed that there was an increase in sugar and TSS content in guava by treatment of various plant growth regulators such as NAD urea and NAA. For better clarification, the effect of different chemicals and cultural practices is discussed in (Fig. 4).



(Agnihotri *et al.*, 2016) [1]

Fig 3: Impact of different chemicals and cultural practices on biochemical characteristics of guava fruits

8.2 Total soluble solids (TSS)

Sweetness of fruit is mainly reflected by the presence of total soluble solids of the fruit. Various thinning approaches gave better results in improvement of TSS in guava fruits during both seasons (Yadav *et al.*, 2022) [65]. Whereas, Sau *et al.*, (2023) [50] perceived a significant enhancement in TSS by chemical treatment with various compounds like DNOC, NAA, 2, 4-D and urea etc. Likewise, (Yadav *et al.*, 2023) [66] recorded the highest TSS content by applying ethephon @ 1800 ppm and urea @ 20 percent during the rainy and winter season. On the other hand, Diwan *et al.*, (2022) [11] described that TSS of guava fruit in the winter and rainy season crop was not influenced by application of chemicals like KI, NAA, urea, and ethephon. Mahendran *et al.*, (2022) [31] stated that bending of shots led to better quality fruits of guava concerning TSS (fig. 4).

8.3 Vitamin C

The ascorbic acid of guava crops is affected by the different crop manipulation treatments. Kumar *et al.*, (2021) [27] also noted the highest ascorbic acid with ethephon 1200 ppm trailed by urea application @15%. Likewise, improved ascorbic acid content with urea 2, 4-D and NAA, has been noted by Senjam *et al.*, (2021) [51] during both seasons (winter and rainy season). Ali *et al.*, (2023) [3] described that bending of shoots gave better quality with highest ascorbic acid content. In another study, Tarkha *et al.*, (2021) [61] observed no significant variation with regard to fruit quality for vitamin C, however, noteworthy improvement in antioxidant characters with ethephon and urea treatments.

8.4 Acidity

Normally the acidity of the fruit is greatly impacted by climate i.e., under summer conditions acidity is lower than winter but in addition to this aspect, various crop manipulation treatments havealso a good influence on fruit acidityas mentioned by several workers. Kumar *et al.*, (2021) [27] also achieved substantial improvement in sugar/acid ratio with various chemical treatments like DNOC, 2, 4-D, NAA and urea as compared to control treatment in both rainy and winter seasons. Samant *et al.*, (2021) [46] stated that bending shoots in June resulted in lesser acidity with higher ascorbic acid content (Fig. 4).

9. Conclusion

Various approaches are practiced for regulation. Successful accomplishment of guava crop regulation depends on judicious use and availability of chemicals including labour and skill including awareness. Among cultural techniques removal of current season growth along with manual removal of 50% summer season flowering in May, is supposed to be the best method. Above all, pruning has been proven to improve and regulate cropping. Pruning also reduces vegetative shoots growth by 36% while application of 2, 4-D at 30 ppm and NAD at 50 ppm, 10 percent urea along with NAA at 200-250 ppm were the best approaches among use of chemicals. Water stress also led to shedding of flowers, leaves and the trees go into dormancy condition.

10. Future line of work

For concrete results, we should emphasize such methods which do not require any kind of chemical. As these chemicals may be harmful to ecology and put extra burden (cost) or grower. Moreover, net profit is also affected. Breeding work and propagation practicesin an efficient manner could be taken up to obtain yield and quality of guava crop.

Establishment of effective somatic embryogenesis protocol for plants depends upon several factors like auxin genotype, carbohydrate source and others; the current review pronounces the latest updates on guidelines of guava crop regulation. Researchers may focus on the genetic improvement of guava as many research gaps need to be filled with advanced technologies. Many transgenic fruit crops are developed with *Agrobacterium tumefaciens*-mediated genetic alteration approach. Till now no studies have described genetic modification through genome editing of guava fruit. Above all, genetically edited guava will

discover the market potential in the future, as guava is a decidedly perishable fruit with prodigious medicinal importance/traits.

11. References

1. Agnihotri MK, Sarolia DK, Singh V, Shukla AK. Crop regulation in guava cv. Sardar as influenced by chemicals and cultural practices under semi-arid conditions of Rajasthan. J Agric Ecol. 2016;1:85-90.
2. Al Mamun MA, Dargusch P, Wadley D, Zulkarnain NA, Aziz AA. A review of research on agrivoltaic systems. Renew Sustain Energy Rev. 2022;161:112351.
3. Ali M. Pruning management in *Psidium guajava* L. orchards - an overview. Gesunde Pflanzen. 2023;75(5):1441-1447.
4. Anthony BM, Minas IS. Optimizing peach tree canopy architecture for efficient light use, increased productivity and improved fruit quality. Agronomy. 2021;11(10):1961-1980.
5. Arredondo E, Chiamolera FM, Casas M, Cuevas J. Comparing different methods for pruning pitaya (*Hylocereus undatus*). Horticulturae. 2022;8(7):661-672.
6. Atal HL, Mitra M. Effect of shoot bending at different time on production and quality of hybrid tea rose cultivar Minu Pearle. Int J Plant Soil Sci. 2023;35(18):978-988.
7. Avelino J, Gagliardi S, Perfecto I, Isaac ME, Liebig T, Vandermeer J, *et al*. Tree effects on coffee leaf rust at field and landscape scales. Plant Dis. 2023;107(2):247-261.
8. Chander S, Kurian RM, Satisha J, Upreti KK, Laxman RH. Advancing fruiting season in Annona cv. Arka Sahan through pruning. J Horticult Sci. 2022;17(2):316-324.
9. Chary GR, Gopinath KA, Raju BM, Rao CA, Kumari VV, Santra P, *et al*. Dryland agriculture. In: Trajectory of 75 years of Indian agriculture after independence. Singapore: Springer Nature Singapore; 2023. p. 577-616.
10. Chun KJ, Bordignon S, Chen S, Schaack D, Urbanek L, Ebrahimi R, *et al*. Findings from repeat ablation using high-density mapping after pulmonary vein isolation with pulsed field ablation. Europace. 2023;25(2):433-440.
11. Diwan G, Jitendra Chandra Chandola, Govind Shiurkar, Narayan Lal. Potential role of plant growth regulators on horticultural crops. Scientist. 2022;1(3):3202-3216.
12. Dutta SK. Plant growth regulators in guava. In: Plant growth regulators in tropical and subtropical fruit crops. CRC Press; 2022. p. 250-261.
13. Fernández-Lobato L, García-Ruiz R, Jurado F, Vera D. Life cycle assessment, C footprint and carbon balance of virgin olive oils production from traditional and intensive olive groves in southern Spain. J Environ Manage. 2021;293:112951-112964.
14. Gill K, Kumar P, Negi S, Sharma R, Joshi AK, Suprun II, *et al*. Physiological perspective of plant growth regulators in flowering, fruit setting and ripening process in citrus. Scientia Horticulturae. 2023;309:111628.
15. GM S, Bhowmick N, Chakraborty A, Dey AN, Ghosh A, Dutta P, *et al*. Effect of shoot pruning on growth, flowering and fruiting characteristics of different guava (*Psidium guajava* L.) cultivars. Int J Fruit Sci. 2022;22(1):686-695.
16. Groh J, Vanderborght J, Pütz T, Vogel HJ, Gründling R, Rupp H, *et al*. Responses of soil water storage and crop water use efficiency to changing climatic conditions: a lysimeter-based space-for-time approach. Hydrol Earth Syst Sci. 2020;24(3):1211-1225.
17. Gupta J, Sharma D, Chauhan A. Classification and suitability of protected structures. In: Protected cultivation. Apple Academic Press; 2024. p. 35-61.
18. Haque MA, Sakimin SZ. Planting arrangement and effects of planting density on tropical fruit crops - A review. Horticulturae. 2022;8(6):485-501.
19. Holmes SM, Ramirez-Lopez J. Fresh fruit, broken bodies: Migrant farmworkers in the United States, updated with a new preface and epilogue. Univ of California Press; 2023;27:8-284.
20. Hossain MA, Amin MN, Sultana J, Siddique MN. Climate change impact on agriculture and related sustainable land management practices in Bangladesh - a review. Int J Environ Climate Change. 2020;10(2):53-69.
21. Ibn-Mohammed T, Mustapha KB, Godsell J, Adamu Z, Babatunde KA, Akintade DD, *et al*. A critical analysis of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies. Resour Conserv Recycl. 2021;164:105169-105190.
22. Ikhlaq M, Bashir MA, Shabir K, Noreen A, Altaf F, Akhtar N. Impact of urea spray on deblossoming of summer crop to enhance productivity in winter crop of guava (*Psidium guajava* L.). J Agric Res (Lahore). 2022;60(2):145-151.
23. Jat R, Kumar V, Singh VP. Deficit irrigation: A potential concept of irrigation for sustainable fruit production under water scarce conditions. Prog Agric. 2023;23(1):81-93.
24. Kamusiime E, Nantongo JS, Wacal C. Insect pests in apple (Malus domestica Borkh) gardens. GSC Adv Res Rev. 2023;15(1):030-053.
25. Kaur J, Jawandha SK, Gill PS, Jan Z, Grewal SK. Composite coatings of beeswax+ naphthalene acetic acid preserved fruit quality and antioxidants in stored lemon fruits. Food Sci Biotechnol. 2024;33(3):589-598.
26. Kowalska J, Antkowiak M, Tymoszuk A. Effect of plant seed mixture on overwintering and floristic attractiveness of the flower strip in Western Poland. Agric. 2023;13(2):467-482.
27. Kumar A, Bhuj BD, Ram S, Singh CP, Dhar S, Yadav RK. Crop regulation in fruit crops: a review. Ann Rom Soc Cell Biol. 2021;25(6):7896-7919.
28. Kumar A, Ram S, Bist LD, Singh CP. High density orcharding in fruit crops: A Review. Ann Rom Soc Cell Biol. 2021;25(6):948-962.
29. Lian HN, Singh B, Wangchu L, Yumkhaibam T, Haokip SW, Sheikh KA. Canopy Manipulation for Production of Winter Guava (*Psidium guajava* L.) in the Eastern Himalayan Region of India. Environ Ecol. 2024;42(1):151-158.
30. Liu K, Harrison MT, Yan H, Liu DL, Meinke H, Hoogenboom G, *et al*. Silver lining to a climate crisis in multiple prospects for alleviating crop waterlogging under future climates. Nat Commun. 2023;14(1):765-777.

31. Mahendran PP, Suganya S, Kannan P, Yuvaraj M. Growth, Nutrient Uptake, Yield and Quality Parameters of Nendran Banana (Musa Spp.): As Influenced by the Application of Boron in Typic Rhodustalf of Theni District, Tamil Nadu, India. Commun. Soil Sci. Plant Anal. 2022;53(5):559-575.
32. Majeed A. Species diversity of fruit flies (Bactrocera spp.) in Guava orchards of Sahanpur District of Uttar Pradesh. J Pharmacogn Phytochem. 2024;13(1):190-195.
33. Mastrangelo T, Kovaleski A, Maset B, Costa MD, Barros C, Lopes LA, *et al*. Improvement of the mass-rearing protocols for the South American fruit fly for application of the sterile insect technique. Insects. 2021;12(7):622-639.
34. Melrose J, Normandeau S. The Prairie Gardener's Go-to for Small Spaces. Touch Wood Editions; 2021:1-18.
35. Michael Menzel C. A review of productivity in strawberry: do the plants need larger canopies, more flowers, or higher CO2 assimilation for higher yields?. J Horticult Sci Biotechnol. 2022;97(6):674-696.
36. Mirbod O, Choi D, Heinemann PH, Marini RP, He L. On-tree apple fruit size estimation using stereo vision with deep learning-based occlusion handling. Biosyst Eng. 2023;226:27-42.
37. Mishra DS, Singh S, Singh AK, Rao VA, Yadav V, Saroj PL. Crop regulation in fruit crops for improving quality and income of farmers. In: Dryland Horticulture 2021. p. 415-434.
38. Momtaz M, Bubli SY, Khan MS. Mechanisms and health aspects of food adulteration: A comprehensive review. Foods. 2023;12(1):199-223.
39. Nanda G, Panda AK, Mansingh B. Crop Lodging and its Management for Reducing Yield Losses in Field Crops. Int Year Millets 2023;2(5):29-32.
40. Nautiyal P, Arora I, Dongariyal A, Pandey S, Semwal A, Agrawal K, *et al*. High Density Planting and Meadow Orcharding in Guava for Higher Return. Int J Environ Clim Change. 2023;13(6):212-218.
41. NHB. India - Production volume of guava 2023. Available from: https://www.statista.com/statistics/1043925/india-production-volume-of-guava/
42. Olatunde A, Ogunro OB, Tijjani H, Shariati MA, Mubarak MS, Rengasamy KR. Chemical constituents and antioxidant potential of African Fruits. S Afr J Bot. 2024;166:126-150.
43. Patel N. Biointensive Integrated Pest Management for Horticultural Crops of Arid Region. In: Horticulture Based Integrated Farming Systems. 2021. p. 361-371.
44. Ranpise SA, Patil BT. Plant Growth Regulators in Grape. In: Plant Growth Regulators in Tropical and Sub-tropical Fruit Crops. 2022.
45. Rodríguez-Moreno VM, Padilla-Ramírez JS, Medina-García G, Reyes-González A. Combined Radiometric Analysis Related to Guava Leaf Phenology in Response to Soil Application of Paclobutrazol (PBZ). Int. J Geosci. 2022;13(8):681-694.
46. Samant D, Kishore K. Response of guava var. Arka Amulya to branch bending during winter and summer in the Eastern tropical region of India. J Environ Biol. 2021;42(3):720-726.
47. Sangamnere R, Misra T, Bherwani H, Kapley A, Kumar R. A critical review of conventional and emerging wastewater treatment technologies. Sustainable Water Resour Manage. 2023;9(2):58.
48. Santhoshkumar GM, Bhowmick N, Chakraborty A, Dey AN, Ghosh A, Dutta P. Response of shoot pruning on growth, flowering and fruiting characteristics of guava under Sub-Himalayan Terai Region of West Bengal. Indian J Ecol. 2022;49(2):502-507.
49. Sathiah N, Murugan M, Suganthi A, Arulprakash R, PS S. Changing pest scenario in vegetable ecosystems. Tamil Nadu agricultural university and NABARD, Chennai. 2021:67-76.
50. Sau S, Maji S, Ghosh B, Datta P. Guava. In: Tropical and Subtropical Fruit Crops. Apple Academic Press. 2023. p. 351-395.
51. Senjam BD, Singh SR. Effects of foliar spray of NAA, 2, 4-D and urea on fruit yield and quality of Citrus limon (L.) Burm. cv. Assam lemon. Bangladesh J Bot. 2021;50(1):189-194.
52. Shankar S, Kumar G, Singh A, Mishra PK. Revealed comparative advantage (RCA) and its application to evaluate India's performance of fresh mangoes, mangosteen & guavas during the period 1991-2020: An analysis with respect to trade. J Contemp Issues Bus Gov. 2023;29(1):396-421.
53. Sharma LD, Sadhukhan R, Hota D. Neutralising Climate Change Through Fruit Crops. Res Rev J Crop Sci Technol. 2021;10(3):28
54. Singh N, Sharma DP, Kumari S, Kalsi K. Techniques for crop regulation in guava-a review. Int J Farm Sci. 2018;8(2):131-135.
55. Singh TN. Effect of branch level and leaf pruning in vegetative growth, yield and quality of guava: A review. Pharma Innov J. 2022;11(1):471-475.
56. Srivastava KK, Kumar D, Singh SR, Barman P, Kumar P. Pruning in guava (*Psidium guajava*)—a review. Curr Hortic. 2022;10(2):12-15.
57. Stout AJ, Rittenberg ML, Shub M, Saad MK, Mirliani AB, Dolgin J, *et al*. A Beefy-R culture medium: replacing albumin with rapeseed protein isolates. Biomaterials. 2023;296:122092-1220111.
58. Tamang P, Saha T, Debnath S. Effect of branch bending time on induction of shoot and flower bud, productivity and quality of guava var. sardar (L-49). J Crop Weed. 2021;17(3):83-90.
59. Tarai RK, Nayak US, Panda AK, Sharma VK, Supe VS, Shete MB, *et al*. Plant Growth Regulators in Pomegranate. In: Plant Growth Regulators in Tropical and Sub-tropical Fruit Crops. 2022. p. 535-563.
60. Tarekegn K, Kelem F. Assessment of mango Post-Harvest losses along value chain in the Gamo zone, southern Ethiopia. Int J Fruit Sci. 2022;22(1):170-182.
61. Tarkha A, Singh P, Singh J. Guava fruit ripening process with ethephon and related chemicals: A. IJRAR Int. J Res Anal Rev. 2021;8(1):170-178.
62. Thind SK, Mahal JS. Package of practices for cultivation of fruits. Additional Director of Communication for Punjab Agricultural University: Ludhiana, India. 2021. p. 1-188.
63. Viljoen CC, Jimoh MO, Laubscher CP. Studies of vegetative growth, inflorescence development and eco-dormancy formation of abscission layers in *Streptocarpus formosus* (Gesneriaceae). Horticulturae. 2021;7(6):120-135.

64. Widyastuti RA, Budiarto R, Warganegara HA, Timotiwu PB, Listiana I, Yanfika H. 'Crystal'guava fruit quality in response to altitude variation of growing location. Biodiversitas J Biol Divers. 2022;23(3):1546-1552.
65. Yadav A, Kumar N, Upadhyay A, Fawole OA, Mahawar MK, Jalgaonkar K, *et al*. Recent advances in novel packaging technologies for shelf-life extension of guava fruits for retaining health benefits for longer duration. Plants. 2022;11(4):547-574.
66. Yadav S, Pratap R, Yadav A, Yadav L, Chaudhary AK, Verma S, *et al*. A Review on Crop Regulation in Guava Fruit. Int. J Environ Clim. Change. 2023;13(10):4444-4452.
67. Zahira A, Sultana S, Rasul A, Sultana T, Hassan M. Hepatoprotective effects of almond shells against carbon tetrachloride induced liver injury in albino rats. Saudi J Biol. Sci. 2023;30(11):103811-103817.