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Strategic pruning for manipulation of cropping cycles to maximize off season yield in guava (*Psidium guajava* L.) cv. Lalit

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ABSTRACT

Guava (Psidium guajava L.) is a wonderful fruit crop responding incredibly well to pruning practices, so pruning is an essential management tool to regulate crop load, manipulate flowering, and improve fruit yield and quality. The current study was planned to assess the impact of different pruning times on growth, blooming, fruiting cycles and qualitative attributes of guava. In this experiment, the pruning operations were performed on 15th April, 30th May, 15th July, 30th August, 15th October and 30th November on the guava cv. Lalit. The results proclaimed that pruning executed on May 30th outperformed the other treatments regarding vegetative growth characteristics such as number of new shoots per branch, minimum days to bud appearance, bud swell, and bud burst. In contrast, the reproductive growth characteristics of guava, including the shortest period to flower bud initiation, 50% flower opening, full bloom, and fruit set, maximum fruit number and yield per plant have all been enhanced following the 30th May pruning. However, the time of pruning had a substantial impact on the quality attributes of guava, trees pruned on 30th May had the highest level of these variables and yielded fruits of relatively superior quality with maximum total sugars, TSS and minimum titratable acidity. A major challange in the study was variation in climatic conditions which affect the plant response to pruning treatments. This study contributes to demonstration of effective pruning techniques which manipulate guava cropping cycles to enhance off-season yield. It provides practical pruning schedules for farmers on optimizing pruning intensity and timing to achieve better fruit availability during market-scarce periods.

Keywords: *attributes, bloom, guava, pruning, quality, shoot, superior, tropical, yield.*

Introduction

Guava (*Psidium guajava* L.) is a key fruit crop grown in tropical and subtropical regions globally, belonging to the Myrtaceae family [7]. From Mexico to Peru, the guava is indigenous to Tropical America. The tree is evergreen and generally hardy in nature. In reference to other fruit crops, guava is well adapted to a greater variety of soil and climatic conditions [18, 20]. In terms of area and production, guava ranks fifth behind mango, citrus, banana, and apple, making it one of India's most important cash crops [13]. In India, the annual production of guava is 52,63,000 MT on an area of about 3,58,000 hectares [2]. Himachal Pradesh produces an estimated 3,330 MT of guava annually on 2,490 hectares of land [2].

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Guava responds effectively to pruning since it bears fruit over the growth of the current season and has blooms that appear sporadically or in cymes of two or three in the axils of its new foliage. An unusual occurrence in and of itself is the production of two or three crops in a single year [11]. The spring flush produces a bumper crop, but the fruits are of low quality and are infected by the fruit fly, which makes it necessary to regulate the guava crop for the winter by pruning.

Fresh fruits are severely deficient during the long lean period (September to May), with over 54% fruits accessible from May to August and fewer than 46% accessible throughout the remaining eight months [10]. To avoid glut in the market and guarantee a consistent fruit supply, crop regulation is favoured [9]. Pruning-induced crop regulation in guava is not standardized for year-round crop production in Himachal Pradesh's subtropical regions. Therefore, this study was planned to standardize the pruning time in the subtropical climate of the state.

Materials and Methods

Geographical location of the experimental site

The trial was conducted during (April 2022- June 2023) at College of Horticulture and Forestry, Neri, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The site is situated at the coordinates of 76°28' 6.3" E longitude and 31°41' 47.6" N latitude with 650 m altitude above mean sea level. Extremely hot summers (May–June) with high temperatures as 40°C and harsh winters (December–January) with low temperatures as 5°C are the region's defining features (Fig. 1).

Methodology

The research was carried out on 6 year-old trees of the guava cv. Lalit was planted in a high-density orchard at a distance of 2m x 2m. There were seven treatments in the whole experiment, along with a control, which were replicated thrice. Treatment combination includes: T_1= 15th April pruning, T_2= 30th May pruning, T_3= 15th July pruning, T_4= 30th August pruning, T_5= 15th October pruning, T_6= 30th November pruning and T_7= Control (normal winter pruning). At 45-day intervals, two leaf pair pruning operations were performed on the entire trees except the control, where normal winter pruning was done on 15th November to remove dead and overlapping branches.

Statistical analysis

Data was analyzed by OPSTAT statistical software using the Randomized Block Design approach. The critical difference at the 5% level of significance was used for evaluating the mean values of each character.

Results

Impact of varying pruning intervals on vegetative growth characteristics of guava

Bud appearance, bud swell and bud burst

The statistical analysis of the present study indicated that the appearance of bud, bud swelling and bud burst is significantly affected by pruning time. The minimum days for bud appear (5.25 days), bud swell (7.75 days) and bud burst (10.58 days) were noted in 30th May pruning (T_2) statistically equivalent to (T_1) 15th April pruning while, maximum days for bud appear (13.52 days), bud swell (18.83 days) and bud burst(24.58 days) were noted in 30th November pruning (T_6) which did- not differ significantly from T_7 (Control) as depicted in in (Table 1; Fig. 2).

Shoot number per branch and leaf number per shoot

Statistical results of this study manifested that pruning time has a major influence on shoot number per branch. In this study, trees pruned on 30th May (T_2) showed the maximum growth of new shoots per branch (12.25), which was statistically comparable to (T_1) 15th April pruning, i.e. (11.85), while the Control (T_7) showed the minimum new shoots per branch (9.09). Simultaneously, maximum leaves per shoot (20.45) were noted in 30th May pruning (T_2), which did not differ significantly from (T_1) 15th April pruning. i.e. (20.06) as presented in (Table 1; Fig. 3).

Impact of varying pruning intervals on reproductive growth attributes of guava

Time taken for the initiation of flower buds

The present study clearly proclaimed that pruning time had a substantial effect on the emergence of flower buds. The minimum time (40.32 days) for flower buds to initiate was observed in 30th May pruning (T_2) which was statistically comparable to (T_2) 15th April pruning i.e. (41.00 days) while, the maximum days (59.05 days) for initiation of flower buds were observed in 30th November pruning (T_6) showing no significant difference from (T_7) Control i.e. (58.89 days) as depicted in (Table 2; Fig. 2).

Flower opening

In the present study, flower opening is significantly impacted by different pruning intervals. Shortest time required for 50% opening of flowers (59.58 days) was recorded in 30th May pruning (T_2) which did not significantly differ from (T_1) 15th April pruning i.e. (60.03 days) while, maximum time required for 50% opening of flowers (86.06 days) was recorded in 15th October pruning (T_5) which was statistically equivalent to (T_7) Control i.e (85.63 days) as presented in (Table 2; Fig. 2).

Time taken for full bloom after pruning

Statistical results of this study manifested that pruning time had significantly affected the days taken to full bloom. The least amount of time required for full bloom (68.11 days) after pruning was recorded in trees pruned on 30th May (T_2) which was statistically comparable to (T_1) 15th April pruning i.e. (69.42 days) while, maximum time required for full bloom (98.36 days) was observed in the trees which were pruned on 15th October (T_5) which did not differ significantly from (T_7) Control i.e. (95.75 days) as represented in (Table 2; Fig. 2).

Days taken to fruit set after pruning

The statistical analysis of the study showed that pruning intervals greatly influenced the time taken for fruit setting in guava. Trees pruned on 30th May (T_2) took the minimum days (77.64 days) for fruit setting, which was statistically comparable to (T_1) 15th April pruning, i.e. (78.12 days), whereas trees pruned on 15th October (T_5) took the maximum days (108.14 days) for fruit setting as depicted in (Table 2; Fig. 2).

Flower number per branch

The results of this study proclaimed that flower number is significantly influenced by different pruning intervals in guava. Trees pruned on 30th May (T_2) had the highest number of flowers per branch (33.44), which did not differ significantly from (T_1) 15th April pruning, i.e. (33.19 days), while, the Control (T_7) had the lowest flower number per branch (21.18) as presented in (Table 2; Fig. 3).

Time taken from fruit set to maturity

The statistical analysis of the data revealed that the time taken from fruit set to maturity was significantly impacted by pruning intervals. Pruning on 30th May (T_2) had the shortest time from fruit set to maturity (66.40 days) which was statistically equivalent to (T_1) 15th April pruning i.e. (67.22 days), whereas trees pruned on 30th August (T_4) had the longest time (79.25 days) showing no significant difference from (T_3) 15th July pruning i.e. (77.96 days) as shown in (Table 2; Fig. 2).

PCA Biplot analysis for Flower development characteristics

Using a Principal Component Analysis (PCA) with several measured variables, the multivariate impact of various treatments on flower development characteristics was assessed (Fig. 4).

A total of 96.8% of the variation in the dataset was described by the first two principal components (PC1 and PC2), which represented 85.7% and 11.1% of the variance. The main associations of PC1 were with growth characteristics like flowers per branch, leaves per shoot, and shoots per branch (negative direction) and timing traits like days to flower bud initiation and bud appearance (days) (positive direction). Days from fruit set to maturity were strongly correlated with PC2.

Higher values for days to flower bud initiation and bud appearance were found for treatments T_6 and T_7, which were situated on the far positive side of PC1. The negative side of PC1 was occupied by T_1, T_2, and T_3, which contributed to increased flowers per branch, leaves per shoot, and shoots per branch. T_5 showed a substantial correlation with the number of days from fruit set to maturity and was situated in the top left quadrant. T_4 showed up close to the origin, suggesting that all of the qualities had comparatively average levels.

Impact of varying pruning intervals on yield contributing parameters

Fruit number per tree and fruit yield per tree

The statistical results of this study manifested that pruning time exerted a significant impact on fruit number as well as on fruit yield. The highest fruit number per tree (81.19) was observed in 30th May pruning (T_2), which did not show any significant difference from (T_1) 15th April pruning, i.e. (80.84) fruits per tree, while, lowest fruit number per tree (57.46) was observed in Control (T_7). Meanwhile, the highest fruit yield per tree (15.12 kg/ tree) was observed in 30th May pruning (T_2) which was statistically comparable to (T_1) 15th April pruning i.e.(14.73 kg/tree) while lowest yield per tree (9.56 kg/ tree) was recorded in Control (T_7) as presented in (Table 3; Fig. 5).

Impact of varying pruning intervals on qualitative characteristics of guava

Physical characteristics

Fruit weight, fruit length and fruit breadth

Pruning time had a substantial influence on the physical characteristics of fruits. The highest reported weight (185.12 g) was recorded in fruits obtained from 30th November pruning (T_6), whereas, lowest weight (172.93 g) was recorded in fruits harvested from 15th April pruning (T_1), which did not significantly differ from (T_2) 30th May pruning, i.e. (174.47g). Meanwhile maximum length (62.50 mm) and breadth (61.71 mm) of fruits were recorded in fruits obtained from 30th November pruning (T_6) while, theminimum length (56.24 mm) and breadth (55.03 mm) were recorded in fruits harvested from 15th April pruning (T_1) as shown in (Table 3; Fig. 6).

Biochemical characteristics

Total Soluble Solids (TSS)

The study had a positive role of pruning time in influencing fruit qualitative traits. Pruning time significantly impacted the total soluble solids in guava. Fruits obtained from 30th May pruning (T_2) reported the highest TSS (11.52 $^{\circ}$B), showing no significant difference from (T_3) 15th July pruning, i.e. (11.47 $^{\circ}$B), whereas the lowest TSS (9.93 $^{\circ}$B) was noted in fruits obtained from 15th April pruning as represented in (T_1) (Table 3; Fig. 7).

Titratable acidity

The statistical analysis of the data in the present study disclosed that titratable acidity is significantly influenced by different pruning intervals.

Lowest- titratable acidity (0.34 %) was noted in fruits obtained from 30th May pruned trees (T_2), which was statistically equivalent to (T_3) 15th July pruning i.e. (0.37%) whereas the highest titratable acidity (0.49 %) was found in fruits obtained from trees pruned on 15th April, as shown in (T_1) (Table 3).

Total sugars, reducing sugars and non- reducing sugars

Statistical results of this study demonstrated that the amount of sugar present in fruits is greatly enhanced with the time of pruning. Fruits obtained from 30th May pruned trees (T_2) recorded maximum total sugars (8.07%), which was statistically similar to (T_3) 15th July pruning i.e (7.95%) while, minimum total sugars (7.17%) was observed in fruits obtained from 15th April pruned trees (T_1). Meanwhile highest content of reducing sugars (5.80%) was noted in fruits obtained from 30th May pruned trees (T_2), showing no significant difference from (T_3) 15th July pruning i.e. (5.75%), while, lowest content of reducing sugars (5.15%) was found in fruits harvested from (T_1) 15th April pruning i.e.(5.15%). Simultaneously, non reducing sugars content was highest recorded in fruits harvested from (T_2) 30th May pruning i.e. (2.31%) which did not significantly differ from (T_3) 15th July pruning i.e.(2.27%), whereas lowest content of non reducing sugars was noted in (T_1) 15th April pruning i.e. (1.95%) as depicted in ((Table 3; Fig. 7).

Vitamin C content and Fruit firmness

Pruning time had a substantial increase in vitamin C content and fruit firmness in guava. Highest Vitamin C content (205.21 mg/ 100g) was observed in fruits obtained from 15th July pruned trees (T_3) which was statistically equivalent to (T_4) 30th August pruning i.e. (202.94 mg/100g) while, lowest vitamin C content (179.55 mg/ 100g) was noted in in fruits harvested from 15th April pruning (T_1). Likewise, high fruit firmness (3.00 kg/ cm^2) was noticed in 15th July pruning (T_3), showing no significant difference from 30th August pruning (T_4), i.e (2.97 kg/ cm^2) whereas low fruit firmness (2.17 kg/cm^2) was noted in fruits harvested from 15th April pruning as presented in (T_1) (Table 3).

PCA Biplot analysis for yield contributing and fruit qualitative parameters

Using a Principal Component Analysis (PCA) with several measured variables, the multivariate impact of various treatments on yield contributing as well as on quality parameters was assessed. PCA biplot (Fig. 8) showed how these traits correlated and how treatments were clustered.

A total of 97.7% of the variation in the dataset was explained by the first two principal components (PC1 and PC2), which shared 55.7% and 42.0% of the total variance. On the constructive side, PC1 was primarily linked to TSS, vitamin C, and total sugars, while, on the negative side, it was linked to titratable acidity. Fruit weight was negatively correlated with PC2, but fruit yield and fruits per plant were strongly positively correlated. Total sugar, vitamin C and TSS levels were high for treatment T_2, positioned on the positive side of PC1. The far positive PC2 zone indicated a high yield and number of fruits per plant, whereas T_6 and T_7 were found to be on the negative side of both factors, indicating that the majority of fruit quality metrics had comparatively lower values.

Extending the harvesting period through pruning

Pruning time had significantly influenced the fruiting cycle and harvesting period in the guava cv. Lalit.

The harvesting period of guava has been extended from the month of September to June by different pruning treatments (Table 4). Crop regulation successfully provides nutrient security during the lean period and guarantees a steady supply of fresh fruits to the consumers.

Discussion

Pruning operations modify the timing of flush, maturity and physiology, which impacts the plant growth and flowering behaviour of various fruit crops [14]. Pruning guava branches enhanced the amounts of polyphenol oxidase, catalase, and peroxidase enzymes in shoots, which improved fruit production and quality [3]. This study found significant differences in guava growth, blooming, fruit production, as well as nutritional content according to varying intervals of pruning.

Vegetative growth characteristics were favoured by early pruning as the prevalence of high temperature and extended photoperiods accelerates the metabolic activity and cell division [6, 11]. Carbon allocation and fluctuations in hormones resulted in increased shoot and leaf number after pruning [8]. In the current experiment, trees pruned throughout the rainy and autumn periods endured extremely low temperatures, declining moisture, and nearly zero rainfall from December to February [19].

Bud differentiation and floral induction are stimulated by summer pruning (April–May), which coincides with longer daylight hours. The growth of new floral buds is encouraged by the enhanced cytokinin action caused by the hormonal [17]. Trees pruned during May have early fruit maturity due to the optimal weather and temperature throughout the fruit growth season, whereas trees pruned later experience fruit maturation that coincides with peak winters, resulting in a delay of fruit maturity [6, 21]. Summer pruning improves the balance between photosynthetic sources (leaves) and sinks (fruits), retaining more flowers and reducing fruit drop, which in turn increases the final yield [5]. Increase in fruit weight, length and breadth is attributed to lesser fruit competition between developing fruits with the delay in pruning time [15]. The greatest ratio of leaf to fruit throughout the winter months allowed pruned plants to produce the most food resources in their leaves, which improves the biochemical attributes of fruits [4, 16]. The rise in total sugar content in fruits derived from summer- pruned trees is potentially related to the degradation of more complex carbohydrates into simple sugars, and also elevated temperatures persisted during the fruit development phase [12, 1]. Low temperatures throughout the fruit ripening stage causes slower respiration and metabolic breakdown, which causes more ascorbic acid accumulation in the fruit tissues [22].

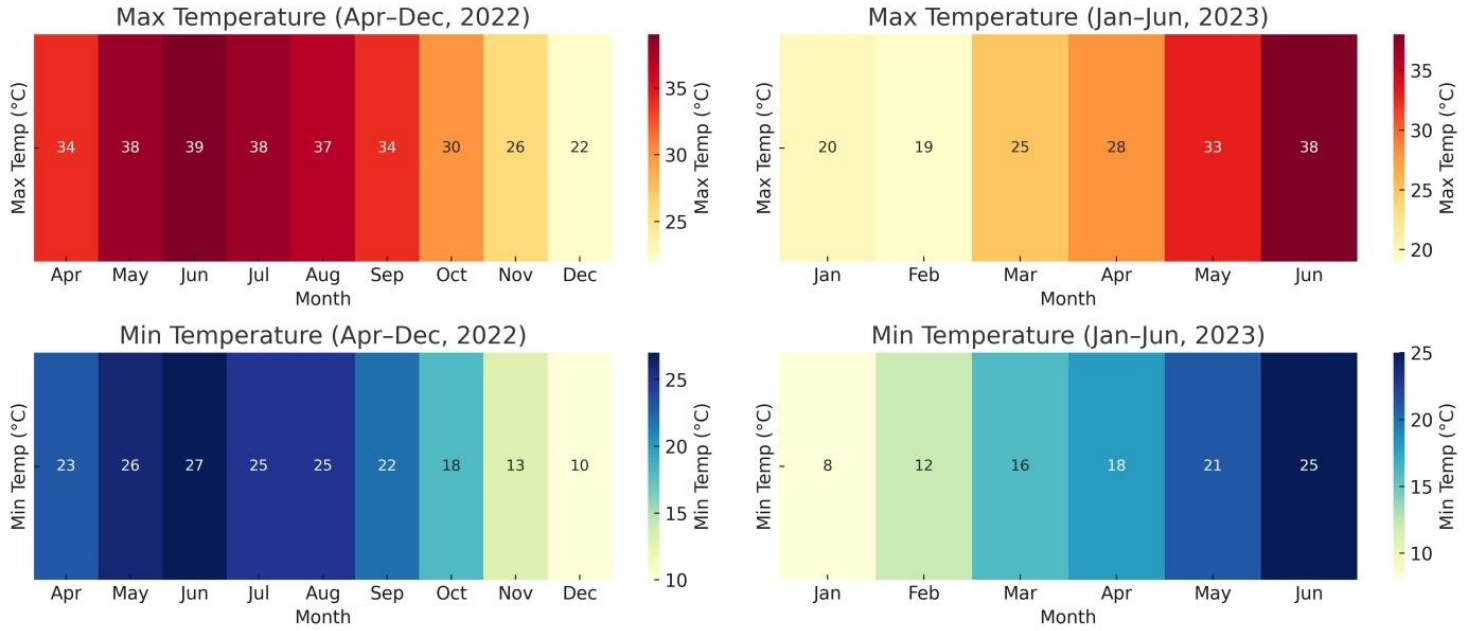

Fig 1. Mean temperature data of experimental site

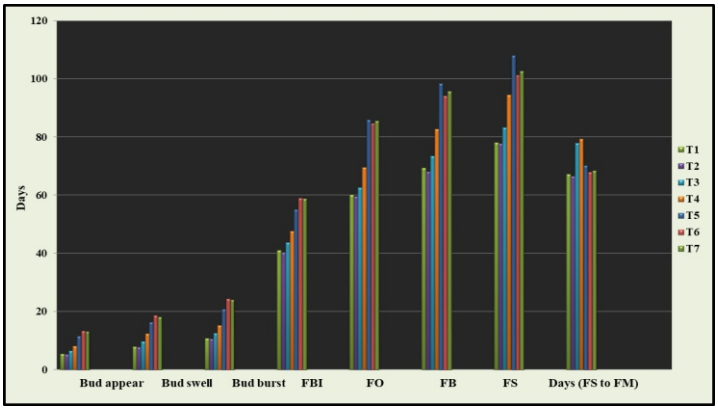

Fig 2. Impact of varying pruning intervals on vegetative and reproductive parameters of guava

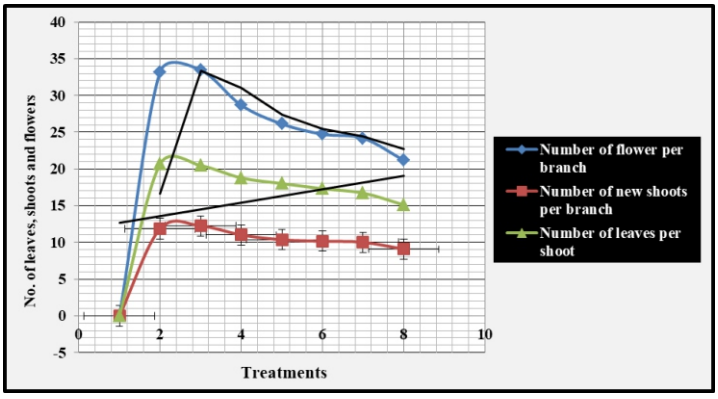

Fig 3. Impact of varying pruning intervals on vegetative growth characteristics of guava

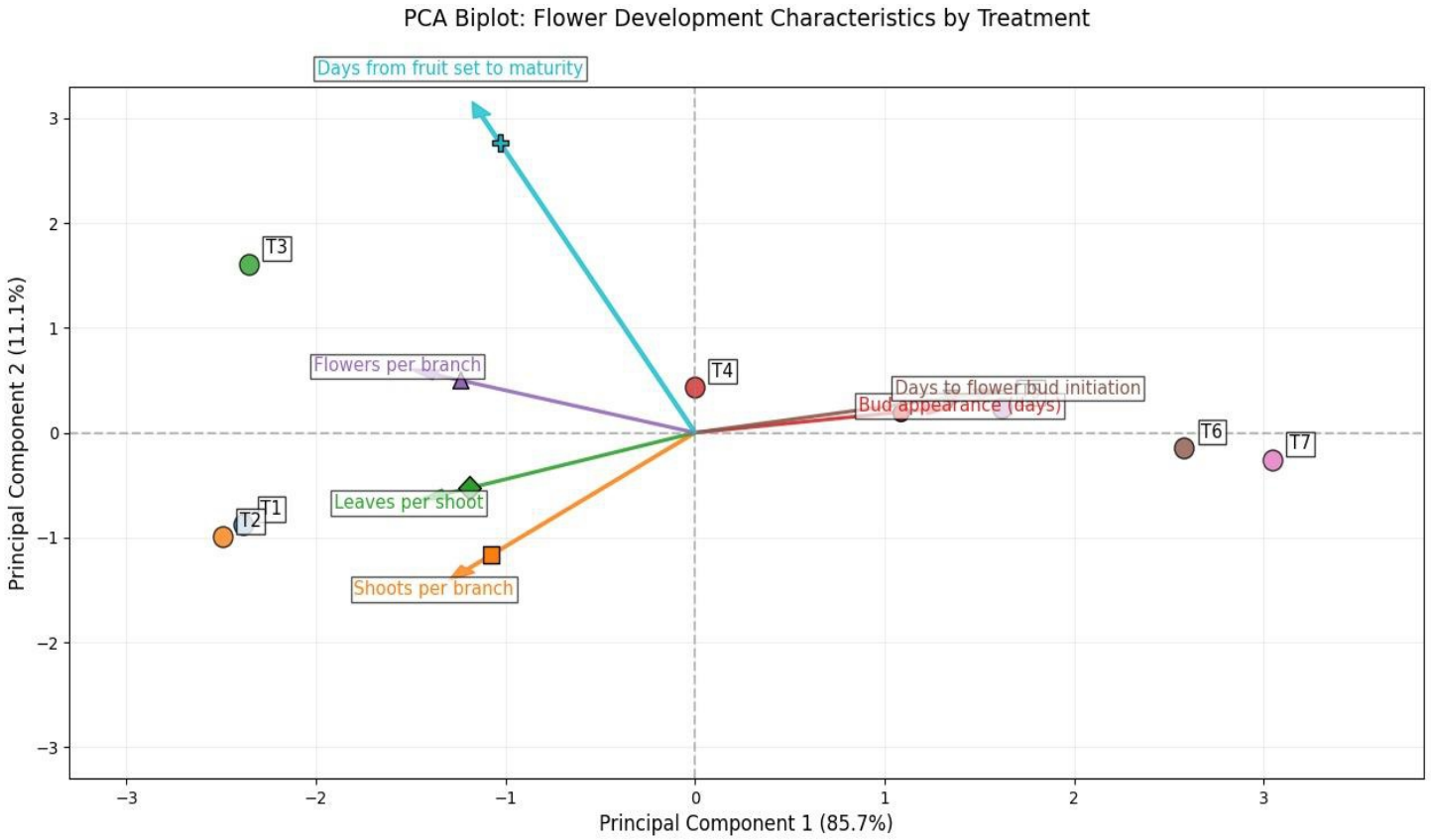

Fig 4. PCA Biplot analysis of growth characteristics of guava

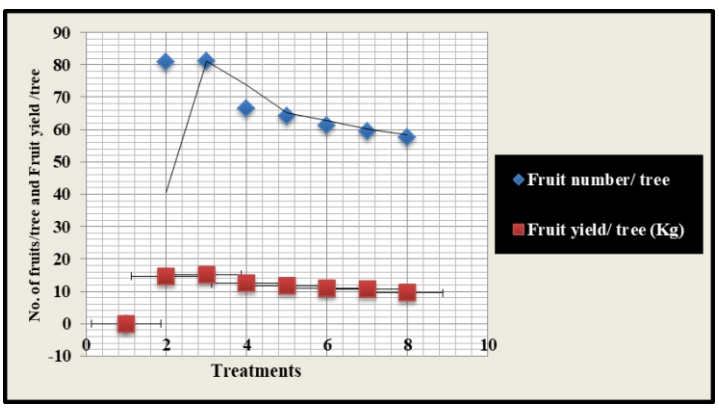

Fig 5. Impact of varying pruning intervals on yield contributing variables of guava

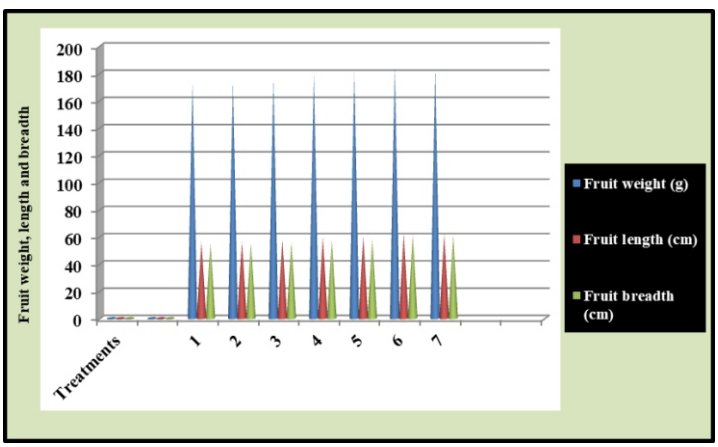

Fig 6. Impact of varying pruning intervals on fruit physical quality parameters of guava

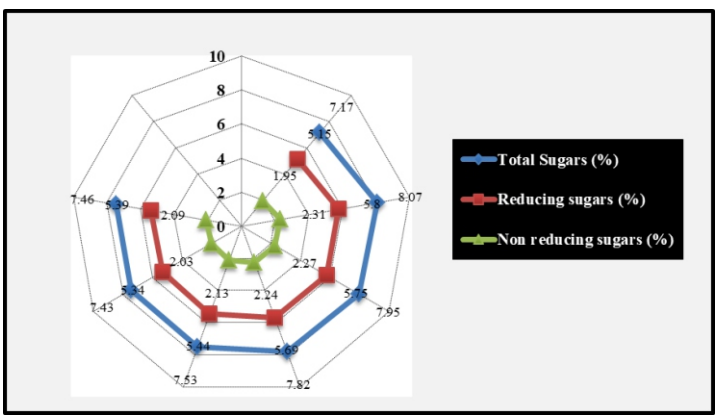

Fig 7. Impact of varying pruning intervals on fruit biochemical parameters of guava

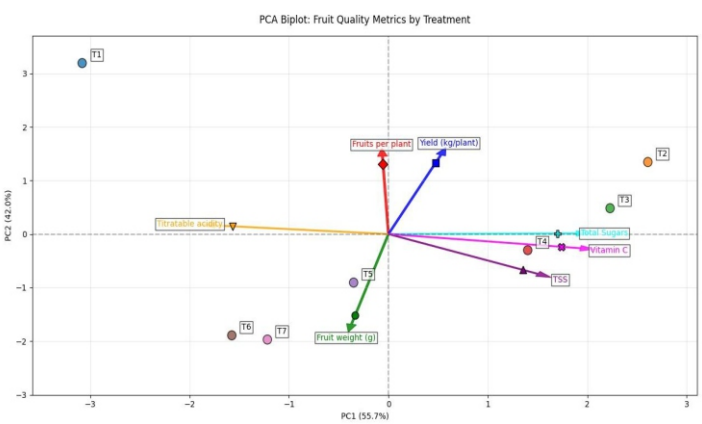

Fig 8. PCA Biplot analysis of yield and fruit qualitative attributes of guava

Table 1. Impact of varying pruning intervals on vegetative growth characteristics of guava

Pruning intervals	Bud appear (days)	Bud swelling (days)	Bud burst (days)	Shoot number per branch	Leaf number per shoot
T_1 (15th April)	5.44	7.92	10.75	11.85	20.66
T_2 (30th May)	5.25	7.75	10.58	12.25	20.45
T_3 (15th July)	6.47	9.64	12.42	11.02	18.78
T_4 (30th August)	8.04	12.39	15.13	10.36	18.01
T_5 (15th October)	11.62	16.58	21.00	10.16	17.31
T_6 (30th November)	13.52	18.83	24.58	10.02	16.72
T_7 (Control)	13.21	18.25	24.08	9.09	15.11
Mean	**9.08**	**13.05**	**16.93**	**10.68**	**18.06**
$CD_{0.05}$	**0.34**	**0.66**	**0.52**	**0.44**	**0.67**

Table 2. Impact of varying pruning intervals on reproductive growth attributes of guava

Pruning intervals	Initiation of flower buds (date)	Days taken to initiation of flower buds	Flower opening after pruning (days)	Full bloom (date)	Days of full bloom after pruning	Days of fruit set after pruning	Number of flower/branch	Days taken from fruit set to maturity
T_1 (15th April)	27-May	41	60.03	27-Jun	69.42	78.12	33.19	67.22
T_2 (30th May)	10-Jul	40.32	59.58	11-Aug	68.11	77.64	33.44	66.4
T_3 (15th July)	30nAugust	43.64	62.57	02-Oct	73.42	83.31	28.67	77.96
T_4 (30th August)	17-Oct	47.58	69.44	19-Nov	82.75	94.44	26.12	79.25
T_5 (15th October)	10-Dec	55.24	86.06	26-Jan	98.36	108.14	24.73	70.35
T_6 (30th November)	30-Dec	59.05	84.68	09-Mar	94.18	101.34	24.18	68.03
T_7 (Control)	14-Jan	58.89	85.63	21-Feb	95.75	102.72	21.18	68.47
Mean	---	**49.39**	**72.57**	---	**80.14**	**92.24**	**27.36**	**71.1**
$CD_{0.05}$	---	**0.76**	**0.58**	---	**2.81**	**2.31**	**0.54**	**1.42**

Table 3. Impact of varying pruning intervals on yield, fruit physical quality and biochemical characteristics of guava

Pruning intervals	Fruit number/ tree	Fruit yield/tree (kg)	Fruit weight (g)	Fruit length (mm)	Fruit breadth (mm)	TSS (°B)	Titratable acidity (%)	Total Sugars (%)	Reducing sugars (%)	Non reducing sugars (%)	Vitamin C (mg/ 100g)
T_1 (15th April)	80.84	14.73	172.93	56.24	55.03	9.93	0.49	7.17	5.15	1.95	179.55
T_2 (30th May)	81.19	15.12	174.46	56.52	55.37	11.52	0.34	8.07	5.8	2.31	199.21
T_3 (15th July)	66.38	12.39	176.29	57.59	56.35	11.47	0.37	7.95	5.75	2.27	205.21
T_4 (30th August)	64.11	11.73	179.42	59.88	57.37	11.38	0.39	7.82	5.69	2.24	202.94
T_5 (15th October)	61.27	10.82	181.05	60.38	58.25	11.2	0.42	7.53	5.44	2.13	191.79
T_6 (30th November)	59.28	10.59	185.12	62.5	61.71	10.86	0.44	7.43	5.34	2.03	187.08
T_7 (Control)	57.46	9.56	183.46	62.23	61.41	10.94	0.43	7.46	5.39	2.09	189.04
Mean	**67.22**	**12.13**	**178.96**	**59.33**	**57.93**	**11.04**	**0.41**	**7.63**	**5.51**	**2.15**	**193.55**
$CD_{0.05}$	**1.83**	**0.54**	**1.68**	**0.34**	**0.39**	**0.28**	**0.04**	**0.15**	**0.07**	**0.05**	**2.64**

Table 4. Impact of varying pruning intervals on harvesting period of guava

HARVESTING PERIOD										
Pruning intervals	**September**	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**
T_1 (15th April)	⟷	⟷								
T_2 (30th May)		⟷	⟷							
T_3 (15th July)				⟷	⟷					
T_4 (30th August)						⟷	⟷			
T_5 (15th October)							⟷	⟷		
T_6 (30th November)								⟷	⟷	
T_7 (Control)									⟷	

Conclusion

This endeavour revealed that vegetative, reproductive, and qualitative attributes of the guava cv. Lalit were greatly impacted by the pruning time. In contrast to normal regulation, which produces fruit for a relatively short period of time, pruning-induced crop regulation in guava prolongs the fruiting period, making guava available for an extended duration.

The goal of regulated crops is to safeguard market surpluses while offering a constant fruit supply. Farm income of guava producers can be increased by pruning practices to regulate fruit production throughout the year and provide raw materials for different processing companies. The primary drawback of processing companies is an irregular and inadequate supply of raw materials; however, we may obtain raw materials for processing industries by regulating the guava crop. It is possible to prevent seasonal losses in surplus guava fruits by processing them into various value- added products that increase their consumer appeal or usefulness. As a result, guava producers can increase their agricultural income.

Future scope of the study

The future scope of this study lies in optimizing guava production through targeted pruning strategies. Research can explore the effects of pruning on different cultivars and in varied climatic conditions to improve off-season yields. Long-term studies can assess the sustainability, cost-effectiveness, and labor requirements of these practices, helping farmers adopt them efficiently. Additionally, exploring the effects of pruning on fruit quality, shelf life, and marketability can provide valuable insights for commercial guava cultivation.

Conflict of interest

The authors declare that they have no conflict of interest.

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Author's contribution

T.R. (Tanvi Rana) conducted the experiment,compiled relevant studies and analysed the data; S.D.S (Som Dev Sharma) conceptualized the research and guided throughout the experiment; V.K.S. (Vikas Kumar Sharma) contributed to critical data analysis; S.K. (Sanjeev Kumar) helped in main manuscript writing; R.D. (Rewa Dhiman) and M.V.(Megha Verma) assisted in editing and formatting.

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