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Research article

Pruning techniques affect flowering, fruiting, yield and fruit biochemical traits in guava under transitory sub-tropical conditions

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ABSTRACT

Production of quality fruits in the dry and low humid October–May period has been a challenge in the tropics and sub-tropics having wide weather fluctuations throughout the year. Henceforth, the research aimed at investigating the seasonal variations in vegetative developments as well as flowering, fruiting, yield, and fruit quality of guava emphasizing the off-seasonality by pruning 0 cm (control), 15 cm, 30 cm, and 45 cm from shoot-tip, once a year at spring (early March), monsoon (early June) and autumn (early September) under such atmospheric implications. Yearly and quarterly documentation at wet (June–August and September–November) and dry (December–February and March–May) seasons revealed that pruning in spring and autumn exhibited statistical parity for higher yearly yield of 31.71 kg and 31.58 kg plant^{-1}, respectively. Moreover, spring pruning had maximum yield in the wet season (23.94 kg plant^{-1}), while autumn pruning governed the dry season production (18.11 kg plant^{-1}) having a notable wet period yield (13.47 kg plant^{-1}). Considering the yearly and quarterly in March–May and December–February harvests, autumn pruning exhibited statistical supremacy for total soluble solids, titratable acidity, total sugar, vitamin C, and specific gravity. However, pruning time didn't influence the fruit physiochemical traits at the June–August and September–November quarters producing fruits of inferior quality compared to those of March–May and December–February harvests. On the other hand, pruning lengths of 30 cm and 45 cm demonstrated statistical consistency for auspicious vegetative, reproductive and fruit biochemical properties. Meanwhile, 30 cm pruning produced maximum number of flowers (224.71 plant^{-1}) and fruits (155.89 plant^{-1}), consequently the highest yield (38.38 kg plant^{-1}). Treatment interactions too ascertained that off-season production of superior quality guava can be enhanced by 30 cm shoot-tip pruning in autumn without compromising the year-round harvests.

1. Introduction

Assurance of nutritional security that everyone has access to adequate availability of fresh or processed healthy and safe food is a major global issue. According to McGuire [1], nutrition security is the secure access to an appropriately nutritious diet along with a

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sanitary environment, adequate health services and care, to ensure a healthy and active life. Hence, fruits are the ample source of phytonutriceuticals, including vitamins (C, A, B1, B6, B9, and E), minerals, dietary fibers, and phytochemicals with secondary metabolites that slacken the risk of chronic diseases. In line with this, fruits play a pivotal role in altering the metabolic activation and detoxification of carcinogens, or even by provoking the processes that alter the course of tumor bodies [2–4]. Reports argued that insufficient fruit and vegetable consumption accounts for 14 %, 11 %, and 9 % of worldwide deaths from gastrointestinal cancer, heart disease, and stroke, respectively [5]. But due to seasonal weather oscillations, fruits are not uniformly available throughout the year being sumptuous in the summer and rainy four months, and scarce in the post-monsoon dry months in the tropics and sub-tropics even in Bangladesh [6–8].

Guava (*Psidium guajava* L.), also known as the 'apple of the tropics' and 'poor man's apple' is one of the most important, highly productive, delicious, and nutritious fruits, grown commercially throughout tropical and sub-tropical regions of the world [9]. The fruits are rich in vitamin C, antioxidants, minerals, dietary fibres, etc. Aside from fresh consumption, fruit is widely used in the processing industry for jam and jelly preparation [10,11]. In Asia, guava has relatively higher demand resulting in cultivation has been drawing paramount attention to the farmers. In line with this, guava is cost-effective, high yielding, and rich in nutritional and medicinal values. Some of the local and registered varieties of guava can bear fruit round the year, if proper management is ensured [12]. However, due to heavy bearing in the regular season (June to September) and a lack of new shoots emergence in the post-monsoon winter, it fails to bear an optimum level of fruits in the lean period (October to May), when a huge demand of fruits prevails in the country. Presently, country's cumulative annual fruit production is about 0.51 million metric tons which is lack behind the demand of target population [13,14] resulting in lower fruit consumption (82 g $person^{-1}$ day^{-1}) against the recommended dietary allowance (200 g $person^{-1}$ day^{-1}). Moreover, more than 54 % of fruits are available from mid-May to mid-August, and less than 46 % of fruits are available during the rest eight months [7] rendering an acute scarcity of native fruits in that lengthy lean period (September to May). Therefore, the availability of fruits in the lean period must be increased in order to ensure nutrient security.

Guava being a well-adapted fruit crop in the country having year-round fruiting potentiality can be one of the possible solutions in this regard. Pruning can be one of the best cultural practices to induce year-round flowering and fruiting in guava. Sahar and Abdel-Hameed [15] proposed that pruning is essential to stimulate the growth of productive shoots and eliminate unproductive shoots, facilitate the plants' maintenance, and form tree canopies in young plants. Sarker et al. [16] and Mitra et al. [17] observed wet season harvest as poor quality, while non-rainy fruits as superior quality. Studies have been reported on different guava cultivars regarding pruning practices and growth and yield attributes [18–21],but the investigation on time and extent of pruning for fruit availability in the lean period is meager. Mitra et al. [17] suggested that light pruning after the annual harvest is essential to encourage new shoots in which flowers and fruits are set. Pruning minimizes space, cost, and labor, and purifies the environment in fruit trees, which ultimately augments the efficiency of plants in performing normal physiological processes for lengthy production [22]. Adhikari and Kandel [18] confirmed that pruning by 20 cm tip removal in early May produced quality fruits both in the rainy and winter seasons. Dubey et al. [23] also reported that pruning influences more sprouting of shoots, flowering, and fruiting, which increases the yield and quality of guava. Therefore, sprouting of new shoots is essential to produce quality guava in the lean period. Considering these, the present investigation was undertaken to find out the suitable pruning strategies with respect to appropriate season and degree of pruning for escalating the production of good quality guava in the lean period not sacrificing the main season yield.

2. Materials and methods

2.1. Experimental site

The experiment was performed from March 2019 to September 2021 at the Fruit Research Farm (23.983°N × 90.408°E) of Pomology Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Gazipur 1701, Bangladesh. The research field was distinguished by silty-clay soil with an average pH of 6.7 under the Madhupur Tract (Agro-ecological Zone, 28) (Supplementary Figure 1). The laboratory works were performed in two laboratories under BARI; the Analytical Laboratory of the Pomology Division, HRC, and the Post-harvest Laboratory of the Post-harvest Technology Division. The climate of the site can be characterized as sub-tropical having a long and warm summer from May to September accompanying heavy precipitation in June to mid-August due to monsoon weather, and a short and dry winter from November to February followed by a quick spring [24].

2.2. General management of plant material

The study was conducted in an 8-year-old guava orchard planted at 5.0 m × 5.0 m spacing. The crop variety was *BARI Peyara-2* (released by Bangladesh Agricultural Research Institute) characterized by main season flowering that occurs in March–April and harvested in August–September with better edible quality [12]. The average plant height, base girth, and tree volume of the studied plant were measured 4.42 m (4.22–4.62 m), 43.34 cm (40.56–47.63 cm), and 271.30 m^3 (258.82–287.12 m^3), respectively at the beginning of the experiment. To manage the plant stature, balanced pruning of dense and overcrowded branches was performed regularly after the monsoon with the help of secateurs in all directions of the canopy to facilitate aeration and light. The cut ends of the pruned branches were smeared with Bordeaux paste ($CuSO_4$: CaO: H_2O = 1:1:4). Recommended fertilization, insect-pest management, and other intercultural operations were practiced starting from the previous growing season.

2.3. Layout and treatment application

The experiment was laid out in a Randomized Complete Block Design with three replications keeping the single plant in each replication. Pruning was performed by removing the 1-year-old shoot tip at four different lengths viz., 0 cm (control), 15 cm, 30 cm, and 45 cm. The pruning practices were conducted in two consecutive years (2019 and 2020) separately at the start of three different seasons namely spring (early March), monsoon (early June), and autumn (early September) where every plant was pruned once a year. The pruning dates were March 5, 2019 and March 2, 2020 for spring pruning, June 4, 2019 and June 3, 2020 for monsoon pruning, and September 2, 2019 and September 2, 2020 for autumn pruning. In each plant, 50 suitable branches were selected, pruned, and tagged for data collection according to the treatment. In control or 0 cm pruning, no pruning was done; 50 shoots were randomly selected all around the plant and tagged for experimental need (Supplementary Figure 1).

2.4. Measurement of growth parameters

The essential vegetative growth attributes responsible for the reproductive behavior of guava were recorded. New shoots started to initiate from the cut stems after pruning. The number of new shoots (cumulative of primary, secondary, and tertiary) and number of leaves per new shoot were recorded monthly and sorted into four groups, viz., March–May, June–August, September–November, and December–February under two major seasons namely wet (June–August and September–November) and dry (December–February and March–May) season. The yearly total number of shoots and leaves per plant was also estimated. Data on days required for the first vegetative bud initiation after pruning, number of leaves and length of shoot up to the first flower bud initiation were recorded by randomly selecting 10 shoots per plant and their averages were calculated. In terms of control, initiation of vegetative bud was noted from the 3rd day after tagging from the selected shoots.

2.5. Assessment of reproductive traits

Reproductive traits like number of days required for the first floral bud initiation, number of flowers and fruits per plant were counted and recorded. Fruits were harvested at color break stage (when the green color of fruits changed to a slightly yellowish color). The number of flowers and fruits per plant was arranged as earlier in March–May, June–August, September–November, and December–February under wet and dry seasons. The yearly total number of flowers and fruits was calculated by cumulating the fruit number of the four quarters. Besides, the fruit set percentage was determined with the following formula (Equation (1)). Ten fruits from each quarter of the year were weighed by a top load electric balance and averaged to attain individual fruit weight. Single fruit weight was then multiplied by the number of fruits per plant at each treatment for each quarter to obtain yield per plant. The total fruit yield per plant in a year was estimated by summing the fruit yield of the four quarters.

$$\text{Fruit set } (\%) = \frac{\text{Number of fruits per plant}}{\text{Number of flowers per plant}} \times 100 \tag{1}$$

2.6. Determination of fruit qualitative attributes

Total soluble solids (TSS), titratable acidity (TA), total sugar (TS), vitamin C (VC), and specific gravity (SG) of fruits were determined quarterly as of vegetative and reproductive traits. Therefore, mean yearly values for TSS, TA, TS, VC, and SG were calculated as per Equation (2). In every parameter ten fruits were randomly selected from each treatment combination and their average values were used. Total soluble solids (TSS) were determined using a digital refractometer (Model: PAL-α, ATAGO, Japan) at room temperature. Results were expressed as percentages. Titratable acidity (TA) was measured as per Ranganna [25] by using 5 g of fruit pulp, homogenized with 20 mL of purified water, and filtered to obtain a pure extract. Each extract (5 mL) was titrated against sodium hydroxide solution (0.1 N NaOH) using a phenolphthalein indicator. Results obtained were expressed in the percentage of citric acid. Vitamin C was measured using 2, 6-dichlorophenol indophenol dye and expressed in mg 100 g^{-1} of fresh fruit [26]. The total sugar content in fruit was estimated according to the procedure of Somogyi (1952) where Bertrand A, Bertrand B, and Bertrand C solutions were used and expressed as the percentage of fresh weight. Specific gravity was determined in the water displacement method [27] and expressed as g mL^{-1} (Equation (3)). All the parameters except individual fruit weight were recorded quarterly i.e., March–May, June–August, September–November, and December–February.

$$\text{Mean yearly X value} = \frac{\Sigma i = 1\text{-}4(\text{Quarterly X value} \times \text{Quarterly fruit numbers of the respective treatment})}{\text{Total number of fruits at that treatment}} \tag{2}$$

Here, X denotes fruit physiochemical attributes like TSS, TA, TS, VC, and SG i = 1–4 represents the four quarters of the year namely March–May (1), June–August (2), September–November (3), and December–February (4)

$$\text{Specific gravity (SG)} = \frac{\text{Fruit weight (g)}}{\text{Volume of water replaced (mL)}} \tag{3}$$

2.7. Statistical analysis

Data collection was started from March, June, and September for spring (March), monsoon (June) and autumn (September) pruning, respectively, and continued until the fruits of the corresponding treatments were completely harvested. Data of the respective parameters were grouped into four categories (March–May, June–August, September–November, and December–February) and analyzed. The other parameters were not grouped and analyzed by using the average values. The main and interaction effects of pruning level and time of pruning were compared using the analysis of variance (ANOVA). Besides, variations in fruit biochemical attributes, regardless of pruning treatments, at the four quarters of the year were also analyzed statistically following one-way ANOVA. Prior to this analysis average of replication one for all the treatment combinations was used as the replication one for every quarters. Similar calculation was done for replication two and three. Mean separation was obtained with Fisher's LSD at the 5 % level of significance ($p < 0.05$). Data analysis was performed using 'R' (version 4.2.2) software.

3. Results

3.1. Weather condition

The experiment site received varied degrees of changes in weather attributes in different months of the year as per observation from the average of three consecutive years (Fig. 1). December was the coldest month (23.74 °C) of the year and April was noted as the hottest month (35.80 °C). The average daily maximum temperature went above 30 °C from March to October and remained below 30 °C in the rest of the months. Again, the average daily minimum temperature was noted as 20 °C and above from March to October, and the mean minimum temperature went as low as 12.14 °C in January. Average monthly relative humidity (RH) followed a simple curve where RH was recorded as a minimum in March (54.44 %). Then it started to advance further and reached a peak in July (90.04 %). More than 80 % RH was recorded during the June to November period. December to March was observed as the less humid months during experimentation. Furthermore, corresponding to the seasonal variations in Bangladesh, comparatively higher rainfall started in May with 14.17 mm/day. Maximum rainfall was recorded maximum in July (17.33 mm/day) then it declined gradually but considerable rainfall occurred till October (9.75 mm/day). A trace amount of rainfall was gauged in the rest cool and dry months from November to March. Average sunshine hours per day were changed reversely with the change of rain during the experiment period. Winter and spring months (November to April) received higher sunshine hours than that of summer and rainy months.

4. Pruning effects on vegetative, reproductive and physiochemical behavior of guava

4.1. Days required for vegetative bud initiation

Significantly ($p < 0.05$) rapid initiation of vegetative buds in 7.27 days was noted in spring pruning having statistical consistency with monsoon pruning (7.44 days), but autumn pruning exhibited delayed vegetative bud initiation (8.87 days) under study (Table 1). Among the pruning degrees, the shortest time (6.99 days) was required at 0 cm pruning, while 45 cm pruning required the longest duration (8.67 days) for vegetative bud emergence having statistical parity with 30 cm pruning (8.32 days). Furthermore, the interaction of time and degree of pruning revealed that T_1L_1 required the shortest time (5.00 days) for vegetative buds which was statistically identical to that of T_2L_1 treatment (5.47 days), however, control plants of the autumn pruning (T_3L_1) took significantly maximum 10.50 days to initiate vegetative bud. Among the pruning-operated plants, vegetative bud development occurred quickly in T_1L_2 (7.17 days) having statistical harmony with T_2L_2 (7.47 days) and T_3L_2 (7.73 days). Statistically similar but higher duration for bud development was required in the case of L_3 and L_4 pruning levels of T_1, T_2, and T_3 (Table 1).

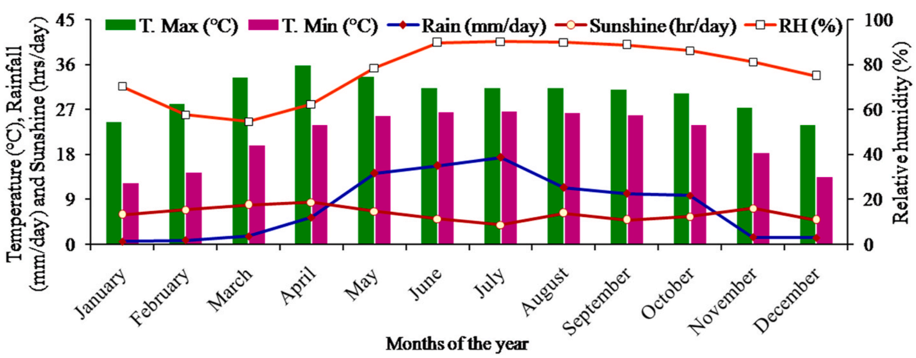

Fig. 1. Average of monthly weather attributes for three consecutive years (2019–2021) at the experiment site.

Table 1
Influence of pruning on vegetative bud initiation, shooting behavior and leaf production in guava.

Treatment	Days required to vegetative bud initiation	Number of new shoots plant^{-1} at different quarters of the year				Total number of new shoots plant^{-1} year^{-1}	Number of new-shoot leaves plant^{-1} at different quarters of the year				Total number of new-shoot leaves plant^{-1} year^{-1}
		Mar.–May	June–Aug.	Sept.–Nov.	Dec.–Feb.		Mar.–May	June–Aug.	Sept.–Nov.	Dec.–Feb.	
Time of pruning											
Spring (T_1)	7.27 ± 0.14b	80.53 ± 3.11a	56.26 ± 3.41b	36.00 ± 2.47c	22.25 ± 1.43b	195.04 ± 5.20	784.19 ± 30.18a	695.24 ± 42.57b	372.36 ± 36.80c	224.91 ± 24.81b	2076.70 ± 84.68
Monsoon (T_2)	7.44 ± 0.21b	51.46 ± 2.83b	81.58 ± 2.83a	44.58 ± 3.03b	23.49 ± 2.32b	201.12 ± 7.98	399.13 ± 83.00b	850.41 ± 68.12a	513.97 ± 52.22b	249.44 ± 22.38b	2013.00 ± 157.67
Autumn (T_3)	8.87 ± 0.23a	52.33 ± 4.20b	49.50 ± 4.20c	55.75 ± 4.39a	37.73 ± 1.63a	195.31 ± 7.99	467.80 ± 34.06b	488.49 ± 80.68c	591.77 ± 44.09a	456.80 ± 17.30a	2004.90 ± 108.27
Degree of pruning											
0 cm (L_1)	6.99 ± 0.17c	45.89 ± 5.19c	49.39 ± 3.38c	20.72 ± 2.64c	19.53 ± 1.76c	135.53 ± 6.84d	317.80 ± 63.55c	477.03 ± 40.57c	176.79 ± 28.26c	145.49 ± 18.20c	1117.10 ± 93.12c
15 cm (L_2)	7.46 ± 0.14b	60.29 ± 4.86b	62.57 ± 2.67b	52.34 ± 3.42b	28.44 ± 1.90b	203.64 ± 7.88c	508.53 ± 50.65b	627.69 ± 74.56b	532.56 ± 49.68b	327.83 ± 29.92b	1996.60 ± 145.76b
30 cm (L_3)	8.32 ± 0.33a	70.56 ± 4.28a	71.28 ± 4.06a	59.77 ± 4.31a	31.22 ± 1.87ab	232.82 ± 5.90a	722.87 ± 41.48a	807.51 ± 68.71a	691.23 ± 59.42a	375.83 ± 26.27a	2597.40 ± 108.91a
45 cm (L_4)	8.67 ± 0.14a	69.03 ± 3.31a	66.56 ± 3.82 ab	48.94 ± 2.83b	32.09 ± 1.66a	216.62 ± 7.60b	652.29 ± 40.65a	799.97 ± 71.32a	570.22 ± 40.12b	392.39 ± 11.59a	2414.90 ± 119.71a
Time of pruning × Degree of pruning											
T_1 L_1	5.00 ± 0.12f	47.67 ± 3.19c	48.50 ± 3.40e	19.33 ± 3.09e	16.33 ± 1.01d	131.83 ± 4.88	323.90 ± 44.30d	454.70 ± 22.32de	164.53 ± 36.44f	116.43 ± 16.26e	1059.60 ± 97.02
L_2	7.17 ± 0.18e	81.20 ± 4.16b	53.03 ± 2.73c-e	37.70 ± 1.85d	23.00 ± 2.18c	194.93 ± 8.46	762.40 ± 34.38b	645.10 ± 55.21cd	353.17 ± 26.42de	240.20 ± 44.65d	2000.80 ± 134.62
L_3	8.40 ± 0.15bc	99.83 ± 3.26a	62.83 ± 4.94c	44.97 ± 1.63cd	23.33 ± 1.17c	230.97 ± 2.24	1163.2 ± 15.45a	881.40 ± 21.74 ab	476.63 ± 45.55cd	256.17 ± 24.99cd	2777.40 ± 33.80
L_4	8.50 ± 0.12bc	93.43 ± 1.84ab	60.67 ± 2.59cd	42.00 ± 3.33cd	26.33 ± 1.36c	222.43 ± 5.20	887.20 ± 26.60b	799.80 ± 71.03bc	495.10 ± 38.77cd	286.85 ± 13.33cd	2469.00 ± 73.29
T_2 L_1	5.47 ± 0.15f	43.50 ± 7.78c	48.83 ± 2.52e	23.67 ± 2.49e	21.17 ± 2.68cd	137.17 ± 9.05	318.20 ± 88.81d	462.60 ± 15.66de	217.87 ± 38.70ef	154.07 ± 16.91e	1152.70 ± 119.10
L_2	7.47 ± 0.09e	49.83 ± 7.37c	90.83 ± 1.64 ab	48.67 ± 2.80bc	22.67 ± 1.92c	212.00 ± 7.94	364.00 ± 97.07d	857.20 ± 99.58a-c	507.30 ± 58.44c	243.90 ± 28.46d	1972.40 ± 181.15
L_3	8.20 ± 0.47cd	55.33 ± 6.61c	99.67 ± 2.84a	56.67 ± 5.20b	25.83 ± 2.68c	237.50 ± 8.58	439.30 ± 81.45cd	1018.5 ± 98.28a	725.42 ± 82.39b	316.93 ± 33.10c	2500.10 ± 212.15
L_4	8.63 ± 0.13bc	57.17 ± 5.13c	87.00 ± 4.33b	49.33 ± 1.64bc	24.30 ± 2.00c	217.80 ± 6.35	475.00 ± 64.67cd	1063.3 ± 53.95a	605.30 ± 29.37bc	282.86 ± 11.05cd	2426.50 ± 117.82
T_3 L_1	10.50 ± 0.25a	46.50 ± 4.58c	50.83 ± 4.23de	19.17 ± 2.35e	21.10 ± 1.57cd	137.60 ± 6.60	311.30 ± 57.54d	513.80 ± 83.71de	147.97 ± 9.65f	165.96 ± 21.43e	1139.00 ± 63.24
L_2	7.73 ± 0.15de	49.83 ± 3.03c	43.83 ± 3.63e	70.67 ± 5.60a	39.67 ± 1.59b	204.00 ± 7.25	399.20 ± 20.50d	380.80 ± 63.90e	737.22 ± 64.17ab	499.40 ± 16.66b	2016.60 ± 121.51
L_3	8.37 ± 0.35b-d	56.50 ± 2.98c	51.33 ± 4.41de	77.67 ± 6.10a	44.50 ± 1.76ab	230.00 ± 6.88	566.10 ± 27.54c	522.60 ± 86.12de	871.65 ± 50.33a	554.39 ± 20.71ab	2514.70 ± 80.33
L_4	8.87 ± 0.18b	56.50 ± 2.96c	52.00 ± 4.54de	55.50 ± 3.51b	45.63 ± 1.61a	209.63 ± 9.24	594.60 ± 30.67c	536.80 ± 88.99de	610.25 ± 52.21bc	607.45 ± 10.40a	2349.10 ± 168.01

Values in the cells are means ± standard errors of three replications. Different letters within the column indicate statistical differences among the treatments according to LSD at $p < 0.05$.

4.2. Number of new shoots

Spring and monsoon pruning produced a significant maximum number of new shoots plant^{-1} in the March–May (80.53) and June–August (81.58) periods, respectively. Besides, autumn pruning governed the development of new shoots plant^{-1} in the next two successive quarters (55.75 and 37.73 in September–November and December–February, respectively). Total number of new shoots plant^{-1} non-significantly ranged from 195.04 to 201.12 upon pruning at different times (Table 1). On the other hand, plants received 30 cm shoot-tip pruning produced maximum number of new shoots plant^{-1} in March–May (70.56), June–August (71.28) and September–November (59.77), while December–February period was led by 45 cm pruning (32.09). Thereby, total number of new shoots plant^{-1} in a year was counted significantly maximum in 30 cm pruning treatment (232.82 plant^{-1}) which was statistically dissonant from all other treatments. Control treatment had minimum number of shoots plant^{-1} at all the quarters (45.89, 49.39, 20.72 and 19.53 in March–May, June–August, September–November and December–January, respectively) as well as total counts in a year (135.53) (Table 1). Besides, interactions exhibited that maximum number of new shoots plant^{-1} in March–May and June–August sessions was noticed in T_1L_3 (99.83) and T_2L_3 (99.67), respectively. On the other hand, plants produced superior number of new shoots in T_3L_3 and T_3L_4 combinations during September–November (77.67 plant^{-1}) and December–February (45.63 plant^{-1}) quarters, respectively. Plants whose shoot tips were not subjected to pruning had statistically minimum number of leaves throughout the experimental period (Table 1).

4.3. Number of new-shoot leaves

Number of leaves plant^{-1} in new-shoot was counted statistically maximum in March–May (784.19) and June–August (850.41), when pruning was done in spring and monsoon, respectively. Autumn pruning manifested maximum leaves in September–November (591.77) and December–February (456.80). Total number of leaves in new shoots plant^{-1} varied from 2004.90 to 2076.70 being higher in spring pruning and lower in autumn pruning (Table 1). Among the pruning degrees, 30 cm pruning generated the highest number of leaves plant^{-1} year^{-1} (2597.40) in new-shoots and 0 cm pruning had the lowest number of leaves plant^{-1} year^{-1} (1117.10 plant^{-1}). Again, being statistically harmonized, 30 cm pruning and 45 cm pruning treatments alternatively produced maximum number of leaves new-shoot^{-1} at all four quarters under observation (Table 1). In the interaction of time and degree of pruning, a significant maximum number of leaves plant^{-1} in the March–May quarter was noted from T_1L_3 (1163.20 leaves plant^{-1}). Likely, T_2L_4 treatment had superior number of leaves in the June–August quarter (10.63.30 plant^{-1}) having statistical unity with T_2L_2 and T_2L_4 combinations. Moreover, the highest number of leaves plant^{-1} was counted in September–November and December–February quarters from T_3L_3 (871.65) and T_3L_4 (607.45), respectively, exhibiting statistical harmony with T_3L_2 in September–November and T_3L_3 in December–February. Overall, the yearly total number of leaves plant^{-1} was marked from 1059.60 (T_1L_1) to 2777.40 (T_1L_3) (Table 1).

4.4. Days required for floral bud initiation

Spring pruning took significantly ($p < 0.05$) minimum of 27.01 days to initiate floral bud, while monsoon pruning led to the floral bud initiation in a maximum of 30.17 days after the pruning operation (Fig. 2A). Among the pruning lengths, a maximum of 33.37 days was required for floral bud development in 45 cm pruning, followed by control (27.93 days), while 15 cm shoot pruning commenced floral buds in the earliest duration (25.97 days) (Fig. 2B). Considering the combination of treatments, floral buds initiated early (24.79 days) in the T_1L_2 combination, while late (35.23 days) flowering was noticed in T_2L_4 treatment (Supplementary Table 1).

4.5. Shoot length and leaf number up to the first floral bud

Statistically ($p < 0.05$) minimum shoot length (15.08 cm) having the lowest number of leaves (8.18) before the first floral bud was registered due to autumn pruning, while monsoon pruning resulted in maximum shoot length (18.07 cm) up to the floral bud having

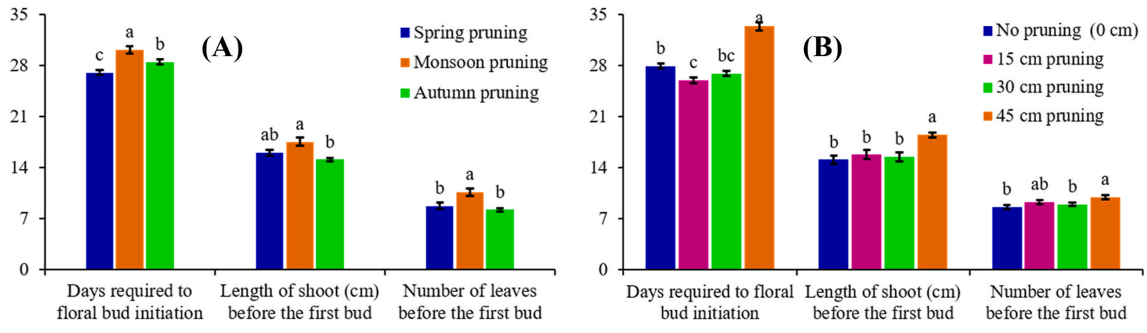

Fig. 2. Days required for floral bud initiation, shoot length (cm) and number of leaves before the first floral bud of guava as influenced by pruning time (A) and degree of pruning (B). Vertical bars on the top of the columns represent the standard errors of means of three replicates. Different letters indicate the statistical differences among the treatments at $p < 0.05$.

greater number of leaves (10.48) (Fig. 2A). Considering the pruning length, the longest shoot (18.49 cm) along with maximum number of leaves (9.91) up to the first floral bud was estimated in 40 cm pruning, while the rest pruning levels had statistically similar shoot lengths up to the first floral bud (Fig. 2B). Moreover, the longest shoot (19.43 cm) with the greater number of leaves (11.43) before the first floral bud initiation was recorded in T_2L_4 as against the shortest shoot (13.60 cm) possessing a lower number of leaves (7.63) up to the first floral bud emergence was noted in T_3L_3 combination (Supplementary Table 1).

4.6. Number of flowers

In the March–May and June–August quarters, guava plants begot with the highest number of flowers after spring pruning (87.08 plant^{-1}) and monsoon pruning (83.93 plant^{-1}), respectively. The lowest number of flowers at those periods were counted in monsoon

Table 2
Flowering and fruiting behabior of guava as influenced by different degrees of pruning performed at different times.

Treatment	Number of flowers plant^{-1} at different quarters of the year				Total number of flowers plant^{-1} year^{-1}	Number of fruits plant^{-1} at different quarters of the year				Total number of fruits plant^{-1} year^{-1}	Fruit set (%)
	Mar.–May	June–Aug.	Sept.–Nov.	Dec.–Feb.		Mar.–May	June–Aug.	Sept.–Nov.	Dec.–Feb.		
Time of pruning											
Spring (T_1)	87.08 ± 3.04a	65.84 ± 4.69b	21.71 ± 2.02c	18.35 ± 1.54b	192.98 ± 11.01	15.78 ± 1.47c	52.35 ± 2.66a	48.38 ± 1.98a	17.01 ± 1.39c	133.51 ± 6.69a	68.66 ± 2.31 ab
Monsoon (T_2)	45.03 ± 4.40b	83.93 ± 4.70a	37.78 ± 3.24b	18.73 ± 1.13b	185.45 ± 9.90	28.07 ± 2.41b	26.89 ± 2.81b	35.73 ± 1.60b	26.06 ± 1.66b	116.75 ± 4.80b	63.23 ± 3.36b
Autumn (T_3)	48.93 ± 3.51b	45.13 ± 3.81c	65.10 ± 3.17a	29.60 ± 2.10a	188.77 ± 10.70	45.87 ± 2.21a	30.68 ± 2.15b	26.78 ± 1.06c	30.04 ± 1.44a	133.36 ± 5.87a	70.23 ± 3.28a
Degree of pruning											
0 cm (L_1)	43.10 ± 2.94b	44.02 ± 3.06c	17.84 ± 2.29c	13.50 ± 1.66c	118.47 ± 9.79c	10.86 ± 1.55c	28.81 ± 2.23b	23.47 ± 1.01c	11.86 ± 0.82c	74.99 ± 4.32c	63.56 ± 4.31
15 cm (L_2)	64.24 ± 4.47a	67.49 ± 5.22b	46.79 ± 2.78b	23.92 ± 1.68b	202.44 ± 10.74b	34.79 ± 2.18b	37.59 ± 2.75a	38.54 ± 1.49b	25.92 ± 1.52b	136.84 ± 6.90b	68.02 ± 3.15
30 cm (L_3)	67.60 ± 3.54a	76.93 ± 3.68a	53.14 ± 3.05a	27.03 ± 1.58a	224.71 ± 10.66a	39.86 ± 2.32a	41.67 ± 2.67a	43.40 ± 2.07a	30.97 ± 1.91a	155.89 ± 6.35a	69.48 ± 5.00
45 cm (L_4)	66.44 ± 3.64a	71.42 ± 5.65 ab	48.33 ± 3.12b	24.44 ± 1.43b	210.64 ± 10.97 ab	34.11 ± 2.06b	38.49 ± 2.51a	42.43 ± 1.65a	28.73 ± 1.73a	143.77 ± 5.58b	68.44 ± 4.90
Time of pruning × Degree of pruning											
T_1 L_1	42.13 ± 2.94c	43.27 ± 3.08e	17.90 ± 2.40e	13.97 ± 1.48d	117.27 ± 9.69	10.83 ± 1.71f	28.00 ± 2.25c	23.80 ± 0.93e	11.37 ± 0.78f	74.00 ± 5.56f	63.19 ± 2.86
L_2	105.30 ± 3.75a	59.93 ± 4.34d	21.03 ± 2.22de	18.40 ± 1.74c	204.67 ± 11.98	15.97 ± 1.73ef	58.40 ± 2.65b	52.30 ± 2.08b	15.73 ± 1.55ef	142.40 ± 7.61cd	69.71 ± 3.01
L_3	103.03 ± 2.63a	86.90 ± 3.59b	25.97 ± 1.76d	21.07 ± 1.88c	236.97 ± 9.03	19.67 ± 1.17e	66.37 ± 3.00a	60.07 ± 2.98a	19.87 ± 1.74de	165.97 ± 6.24a	70.43 ± 6.81
L_4	97.87 ± 2.83a	73.27 ± 7.80c	21.93 ± 1.67de	19.97 ± 1.07c	213.03 ± 13.34	16.63 ± 1.27ef	56.63 ± 2.71b	57.33 ± 1.94 ab	21.07 ± 1.51f	151.67 ± 7.37a-c	71.32 ± 4.48
T_2 L_1	45.10 ± 2.87c	43.43 ± 2.28e	18.47 ± 2.35de	13.37 ± 1.33d	120.37 ± 8.82	11.00 ± 1.63f	29.17 ± 2.29c	23.27 ± 1.10e	12.30 ± 1.01f	75.73 ± 2.96f	63.23 ± 5.79
L_2	43.07 ± 5.52c	98.60 ± 7.53a	38.53 ± 2.53c	20.20 ± 1.03c	200.40 ± 6.54	30.10 ± 2.16d	24.97 ± 3.47c	39.80 ± 1.87c	28.13 ± 2.03c	123.00 ± 7.41e	61.76 ± 3.52
L_3	42.27 ± 4.57c	98.47 ± 3.78a	50.27 ± 4.56b	22.33 ± 0.93c	213.33 ± 11.31	37.87 ± 3.19c	27.17 ± 2.79c	40.10 ± 1.85c	33.60 ± 1.79b	138.73 ± 5.13c-e	65.17 ± 3.71
L_4	49.67 ± 4.63bc	95.20 ± 5.20ab	43.83 ± 3.53bc	19.00 ± 1.22c	207.70 ± 12.95	33.30 ± 2.67cd	26.27 ± 2.70c	39.77 ± 1.57c	30.20 ± 1.79bc	129.53 ± 3.70de	62.77 ± 3.24
T_3 L_1	42.07 ± 3.02c	45.37 ± 3.82e	17.17 ± 2.13e	13.17 ± 2.16d	117.77 ± 10.86	10.73 ± 1.32f	29.27 ± 2.15c	23.33 ± 0.99e	11.90 ± 0.67f	75.23 ± 4.45f	64.27 ± 4.27
L_2	44.37 ± 4.13c	43.93 ± 3.78e	80.80 ± 3.59a	33.17 ± 2.28b	202.27 ± 13.71	58.30 ± 2.65 ab	29.40 ± 2.12c	23.53 ± 0.52e	33.90 ± 0.98b	145.13 ± 5.69b-d	72.58 ± 2.92
L_3	57.50 ± 3.41b	45.43 ± 3.66e	83.20 ± 2.84a	37.70 ± 1.94a	223.83 ± 11.64	62.03 ± 2.62a	31.47 ± 2.20c	30.03 ± 1.39d	39.43 ± 2.20a	162.97 ± 7.68 ab	72.85 ± 4.48
L_4	51.80 ± 3.47bc	45.80 ± 3.97e	79.23 ± 4.14a	34.37 ± 2.00ab	211.20 ± 6.61	52.40 ± 2.25b	32.57 ± 2.12c	30.20 ± 1.45d	34.93 ± 1.91ab	150.10 ± 5.67a-c	71.23 ± 6.99

Values in the cells are means ± standard errors of three replications. Different letters within the column indicate statistical differences among the treatments according to LSD at $p < 0.05$.

pruning (45.03 plant^{-1}) and autumn pruning (45.13 plant^{-1}), respectively. In the rest of the two quarters, the number of flowers plant^{-1} was recorded as maximum in September–November (65.10) and December–February (29.60) when pruning operation was done in autumn, as compared to minimum number of flowers plant^{-1} in the spring (21.71 and 18.35 plant^{-1} in September–November and December–February, respectively) (Table 2). Moreover, a significantly superior number of flowers plant^{-1} (67.60, 76.93, 53.41, and 27.03 in March–May, June–August, Spetember-November and December–February, respectively) was observed in 30 cm pruning treatment, followed by 45 cm pruning (66.44, 71.42, 48.33, and 24.44 in March–May, June–August, Spetember-November and December–February, respectively), while inferior flowering (43.10, 44.02, 17.84, and 13.50 in March–May, June–August, Spetember-November and December–February, respectively) occurred in non-pruned plants (Table 2). At the end of the year, 30 cm pruning treatment confirmed the greatest total number of flowers plant^{-1} (224.71) similar to that of 45 cm pruning (210.64), while minimum number of flowers plant^{-1} was registered in control (118.47) (Table 2). Concerning to the interaction, the number of flowers plant^{-1} in March–May (105.30) and June–August (98.60) periods was governed by T_1L_2 and T_2L_2, respectively. Statistically superior number of flowers was noted in September–November (83.20) and December–February (37.70) quarters from the T_3L_3 combination. Plants under control pruning consideration had inferiority in flower number. The total number of flowers plant^{-1} year^{-1} ranged from 236.97 in T_1L_3 to 117.17 in T_1L_1 (Table 2).

4.7. Number of fruits

Spring pruning resulted in a significantly ($p < 0.05$) increased number of fruits plant^{-1} over the other two pruning time treatments in both June–August (52.35) and September–November (48.38) quarters. The lowest number of fruits plant^{-1} in those periods was obtained from monsoon pruning (26.89) and autumn pruning (26.78), respectively. However, in the March–May and December–February quarters, a significant maximum number of fruits plant^{-1} (45.87 and 30.04, respectively) was harvested from plants that were pruned in autumn, while spring-pruned plants produced minimum number of fruits plant^{-1} in those two quarters (15.78 and 17.01, respectively). Cumulatively, spring pruning gave maximum number of fruits plant^{-1} year^{-1} (133.51), being statistically similar to that of autumn pruning (133.36) as compared to minimum (116.75) in monsoon pruning (Table 2). In the case of pruning lengths, shoot-tip removal by 30 cm produced the highest number of fruits plant^{-1} in quarters (39.86, 41.67, 43.40, and 30.97 in March–May, June–August, September–November, and December–February periods, respectively) as well as in a year (155.89), however, 40 cm pruning produced a statistically identical number of fruits plant^{-1} with 30 cm pruning in June–August (38.49), September–November (42.43) and December–February (28.73). Plants not subjected to pruning gave statistically minimum fruits throughout the observation period (Table 2). Further, a combination study revealed that T_3L_3 had statistically maximum number of fruits plant^{-1} in March–May (62.03) and December–February (39.43) trimesters. On the other side, in both June–August and September–November durations, maximum number of fruits plant^{-1} (66.37 and 60., respectively) was harvested from T_1L_3 treatment combination. Resultantly, the total number of fruits in a year was demonstrated maximum in T_1L_3 combination (165.97 fruits plant^{-1} year^{-1}) having statistical harmony with T_1L_4 (151.67 fruits plant^{-1} year^{-1}), T_3L_3 (162.97 fruits plant^{-1} year^{-1}) and T_3L_4 treatment (150.10 fruits plant^{-1} year^{-1}). Control plants of each observation had minimum fruits plant^{-1} from the beginning to the end of the study (Table 2).

4.8. Fruit set percentage

The fruit set percentage was estimated the highest (70.23 %) in autumn pruning, which was statistically at par with that of spring pruning (68.66 %). While, monsoon pruning resulted in minimum fruit set (63.23 %) plant^{-1} (Table 2). Due to the execution of pruning at different degrees, the fruit set of guava ranged between 63.23 % in monsoon and 70.23 % in autumn pruning. Concerning to the degree of pruning, fruit set percentage was recorded higher in 30 cm pruning as compared to lower in no pruning. Whether, the interaction of pruning time and pruning level revealed that the fruit set percentage of the studied guava plants varied from 61.76 % (T_2L_2) to 72.85 % (T_3L_3) (Table 2).

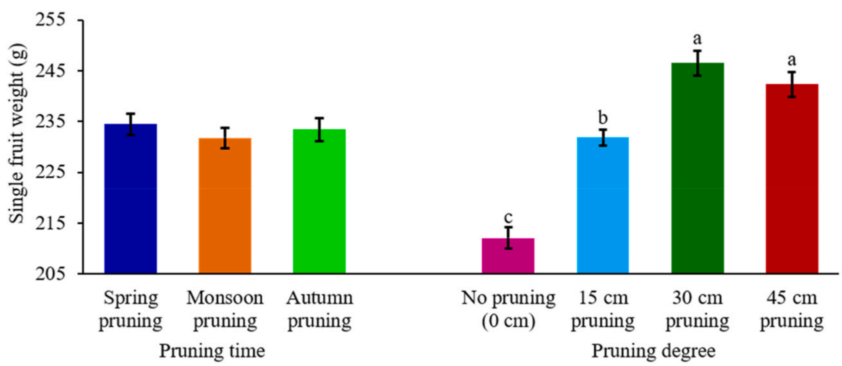

Fig. 3. Single fruit weight of guava (g) as influenced by time and level of pruning. Vertical bars on the top of the columns represent the standard errors of means of three replicates. Different letters indicate the statistical differences among the treatments at $p < 0.05$.

4.9. Single fruit weight

The weight of individual fruit didn't vary with the pruning time ranging from 231.77 g to 234.45 g fruit^{-1}. However, single fruit weight was changed significantly due to the pruning at different levels. The heaviest fruit (246.51 g) was recorded in 30 cm pruning, closely followed by 45 cm shoot-tip removal treatment (242.37 g). Control treatment produced the lightest fruit (212.09 g fruit^{-1}) (Fig. 3). In combination, fruit weight ranged between 212.09 g in T_2L_1 to 248.47 g in T_2L_3 (Supplementary Table 2).

4.10. Fruit yield

Fruit yield at different quarters and total yearly yield were significantly influenced by the main and interaction effect of pruning at different times and levels (Fig. 4, Supplementary Table 2). While observing the quarterly yield, it was found that autumn pruning yielded statistically maximum fruit in March–May (10.96 kg plant^{-1}) and December–February (7.15 kg plant^{-1}) followed by monsoon pruning, spring pruning resulted in minimum fruit yield in those two quarters (3.74 kg and 4.03 kg plant^{-1}, respectively). Meanwhile in June–August and September–November periods, fruit yield was measured the highest at spring pruning treatment (12.43 kg and 11.51 kg plant^{-1}, respectively) (Fig. 4A). Total fruit yield was estimated higher in spring pruning (31.71 kg plant^{-1} year^{-1}) being statistically at par with autumn pruning (31.58 kg plant^{-1} year^{-1}). Regarding the degrees of pruning, significantly maximum seasonal fruit yield in plants with 30 cm shoot-tip pruning made the highest yearly total yield (38.76 kg plant^{-1}). Markedly, 45 cm pruning treatment either followed or exhibited statistical harmony with 30 cm pruning treatment for quarterly and total fruit yield plant^{-1} (Fig. 4B). Moreover, the combination implied that a maximum of 15.19 kg of guava plant^{-1} in the March–May duration and 9.66 kg of guava plant^{-1} in the December–February period was harvested from T_3L_3. During June–August and September–November periods, the utmost fruit yield was registered from the treatment combination of T_1L_3 (16.30 kg and 14.74 kg plant^{-1}, respectively). Ultimately, total fruit yield was assessed maximum of 40.75 kg plant^{-1} in the T_1L_3 combination which was statistically in consonant with T_1L_4, T_3L_3, and T_3L_4 (Supplementary Table 2).

4.11. Total soluble solids (TSS)

Significantly maximum TSS content of fruits in March–May (9.85 %) and December–February (9.75 %) trimesters was determined in autumn pruning, while minimum of the same sessions was estimated in spring pruning (8.87 % and 8.88 %, respectively). However, TSS content of June–August and September–November quarters ranged between 7.42 % to 7.44 % and 8.19 %–8.42 %, respectively. The mean yearly TSS content of fruits was assessed as maximum in autumn pruning (8.46 %) and minimum (7.61 %) in spring pruning (Table 3). Meanwhile, pruning by 45 cm exhibited higher TSS content in March–May (9.66 %) and December–February (9.66 %) having statistical consistency with 30 cm pruning. Shoot pruning by 30 cm also demonstrated maximum TSS in September–November period (8.56 %) as well as maximum mean yearly TSS (8.45 %) (Table 3). The TSS contents of interactions were determined statistically maximum in March–May (10.40 %) from T_3L_4 and in November–December (10.30 %) from T_3L_3 combinations. Pruning time in combination with no-pruning had statistically minimum fruit TSS. Interaction TSS didn't vary statistically in the June–August and September–November quarters (Table 3).

4.12. Titratable acidity (TA)

Pruning at different times didn't influence the titratable acidity (TA) content of guava in the middle two quarters (June–August and September–November). In March–May and December–February, TA was measured as maximum of 0.259 % and 0.294 %, respectively, from monsoon pruning. However, mean yearly TA was observed to be the highest (0.305 %) in spring pruning as compared to the lowest (0.282 %) in autumn (Table 3). With the increase in severity of pruning, TA in fruit decreased, where maximum (0.264, 0.370, 0.317 and 0.260 % in March–May, June–August, Spetember-November, and December–February, respectively) TA was estimated in

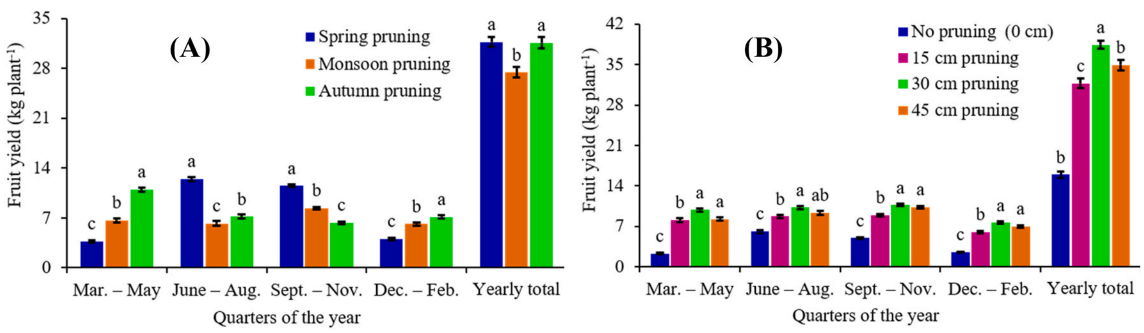

Fig. 4. Quarterly and yearly varaitions in fruit yield of guava as influenced by pruning time (A) and degree of pruning (B). Vertical bars on the top of the columns represent the standard errors of means of three replicates. Different letters indicate the statistical differences among the treatments at $p < 0.05$.

Table 3
Quarterly and yearly variations in total soluble solids and titratable acidity content of guava as influenced by pruning time, pruning level, and their combinations.

Treatment	Total soluble solids (TSS) content (%) of fruits at different quarters of the year				Mean yearly TSS content (%) of fruits	Titratable acidity (TA) content (%) of fruits at different quarters of the year				Mean yearly TA content (%) of fruits
	Mar.–May	June–Aug.	Sept.–Nov.	Dec.–Feb.		Mar.–May	June–Aug.	Sept.–Nov.	Dec.–Feb.	
Time of pruning										
Spring (T_1)	8.87 ± 0.24b	7.44 ± 0.22	8.19 ± 0.27	8.88 ± 0.27c	8.07 ± 0.24c	0.258 ± 0.008a	0.336 ± 0.010	0.308 ± 0.009	0.250 ± 0.009a	0.305 ± 0.008a
Monsoon (T_2)	9.20 ± 0.25b	7.43 ± 0.22	8.42 ± 0.30	9.25 ± 0.23b	8.55 ± 0.24b	0.259 ± 0.009a	0.352 ± 0.012	0.317 ± 0.011	0.254 ± 0.009a	0.299 ± 0.008a
Autumn (T_3)	9.85 ± 0.22a	7.42 ± 0.26	8.42 ± 0.31	9.75 ± 0.21a	8.96 ± 0.25a	0.243 ± 0.006b	0.348 ± 0.012	0.304 ± 0.009	0.238 ± 0.006b	0.282 ± 0.004b
Degree of pruning										
0 cm (L_1)	8.77 ± 0.23c	7.21 ± 0.20	7.87 ± 0.34b	8.74 ± 0.19b	7.88 ± 0.24b	0.264 ± 0.007a	0.370 ± 0.010a	0.317 ± 0.014a	0.260 ± 0.007a	0.320 ± 0.006a
15 cm (L_2)	9.21 ± 0.24b	7.43 ± 0.20	8.41 ± 0.26a	9.13 ± 0.28b	8.54 ± 0.26a	0.259 ± 0.009ab	0.349 ± 0.012b	0.316 ± 0.010a	0.250 ± 0.008 ab	0.298 ± 0.009b
30 cm (L_3)	9.59 ± 0.24ab	7.59 ± 0.32	8.56 ± 0.31a	9.63 ± 0.26a	8.87 ± 0.25a	0.248 ± 0.008bc	0.337 ± 0.012bc	0.314 ± 0.008a	0.240 ± 0.006b	0.286 ± 0.005bc
45 cm (L_4)	9.66 ± 0.24a	7.49 ± 0.21	8.54 ± 0.26a	9.66 ± 0.21a	8.82 ± 0.22a	0.241 ± 0.007c	0.324 ± 0.012c	0.291 ± 0.007b	0.239 ± 0.009b	0.276 ± 0.006c
Time of pruning × Degree of pruning										
T_1 L_1	8.77 ± 0.26d	7.30 ± 0.15	7.87 ± 0.26	8.70 ± 0.23d	7.91 ± 0.21	0.267 ± 0.007	0.357 ± 0.009	0.320 ± 0.012	0.267 ± 0.009	0.318 ± 0.008
L_2	8.80 ± 0.17d	7.40 ± 0.23	8.13 ± 0.29	8.70 ± 0.32d	7.97 ± 0.27	0.260 ± 0.012	0.343 ± 0.013	0.317 ± 0.012	0.250 ± 0.012	0.314 ± 0.013
L_3	8.97 ± 0.27cd	7.60 ± 0.29	8.37 ± 0.26	9.00 ± 0.29b-d	8.20 ± 0.24	0.253 ± 0.009	0.330 ± 0.006	0.307 ± 0.003	0.240 ± 0.006	0.302 ± 0.003
L_4	8.93 ± 0.26cd	7.47 ± 0.20	8.40 ± 0.26	9.10 ± 0.23b-d	8.21 ± 0.24	0.250 ± 0.006	0.313 ± 0.012	0.287 ± 0.009	0.243 ± 0.009	0.287 ± 0.007
T_2 L_1	8.73 ± 0.23d	7.23 ± 0.26	7.87 ± 0.32	8.67 ± 0.18d	7.88 ± 0.25	0.270 ± 0.010	0.363 ± 0.009	0.323 ± 0.015	0.260 ± 0.010	0.321 ± 0.010
L_2	9.00 ± 0.26cd	7.50 ± 0.17	8.50 ± 0.26	9.10 ± 0.29b-d	8.56 ± 0.26	0.267 ± 0.009	0.353 ± 0.012	0.323 ± 0.012	0.257 ± 0.009	0.300 ± 0.010
L_3	9.43 ± 0.23b-d	7.57 ± 0.32	8.67 ± 0.35	9.60 ± 0.26a-c	8.89 ± 0.27	0.257 ± 0.007	0.353 ± 0.017	0.317 ± 0.009	0.250 ± 0.006	0.291 ± 0.007
L_4	9.63 ± 0.27bc	7.43 ± 0.15	8.65 ± 0.26	9.63 ± 0.20 ab	8.88 ± 0.19	0.243 ± 0.009	0.337 ± 0.012	0.303 ± 0.009	0.250 ± 0.012	0.282 ± 0.006
T_3 L_1	8.80 ± 0.21d	7.10 ± 0.17	7.88 ± 0.45	8.87 ± 0.18cd	7.86 ± 0.26	0.257 ± 0.003	0.390 ± 0.012	0.303 ± 0.015	0.253 ± 0.003	0.322 ± 0.001
L_2	9.83 ± 0.30ab	7.40 ± 0.21	8.60 ± 0.23	9.60 ± 0.23a-c	9.09 ± 0.26	0.250 ± 0.006	0.350 ± 0.010	0.310 ± 0.006	0.243 ± 0.003	0.278 ± 0.005
L_3	10.38 ± 0.20a	7.62 ± 0.35	8.63 ± 0.32	10.30 ± 0.23a	9.51 ± 0.26	0.233 ± 0.009	0.327 ± 0.013	0.320 ± 0.012	0.227 ± 0.007	0.266 ± 0.005
L_4	10.40 ± 0.17a	7.57 ± 0.29	8.57 ± 0.26	10.23 ± 0.20a	9.38 ± 0.22	0.230 ± 0.006	0.323 ± 0.012	0.283 ± 0.003	0.227 ± 0.007	0.260 ± 0.004

Values in the cells are means ± standard errors of three replications. Different letters within the column indicate statistical differences among the treatments according to LSD at $p < 0.05$.

control pruning (no pruning or 0 cm pruning). Minimum (0.241, 0.324, 0.291, and 0.239 % in March–May, June–August, Spetember-November, and December–February, respectively) TA was recorded in 45 cm pruning, having statistical parity with 30 cm pruning treatment. There was no significant interaction between pruning time and degree of pruning (Table 3).

4.13. Total sugar (TS)

Statistically maximum total sugar (TS) in March–May (7.10 %) and December–February (6.87 %) trimesters was estimated in autumn pruning, whereas TS in June–August (5.63 %) was found maximum in spring. Contrarily, minimum TS in March–May (6.19 %), June–August (5.31 %), and December–February (6.18 %) were measured from spring and autumn pruning, respectively. Finally, fruits of autumn-pruned plants exhibited maximum mean TS (6.41 %) in a year over others (Table 4). Considering the pruning degree, fruits from 30 cm pruning had statistically significant and maximum TS content throughout the year except in March–May quarter, when it was found maximum (6.91 %) in 45 cm pruning. It was also noticed that 30 cm and 45 cm pruning had statistical similarity in all the cases for total sugar content in fruits (Table 4). In addition, the interaction effect showed that TS content in March–May period was demonstrated significantly the highest (7.59 %) in T_3L_4, having statistical parity with T_3L_3 (7.57 %) and T_3L_2 (7.20 %) combinations. While, the lowest TS content in that quarter was noticed in T_1L_1 (6.03 %) which had statistical consonance with T_1L_2 (6.13 %), T_1L_3 (6.31 %), T_1L_4 (6.27 %), T_2L_1 (6.04 %), T_2L_2 (6.36 %), and T_3L_1 (6.06 %) combinations. In December–February quarter,

Table 4
Quarterly and yearly variations in total sugar and vitamin C content of guava as influenced by pruning time, pruning level and their combinations.

Treatment		Total sugar (TS) content (%) of fruits at different quarters of the year				Mean TS content (%) of fruits	Vitamin C (vit-C) content (mg 100 g^{-1}) of fruits at different quarters of the year				Mean vit-C content (mg 100 g^{-1}) of fruits
		Mar.–May	June–Aug.	Sept.–Nov.	Dec.–Feb.		Mar.–May	June–Aug.	Sept.–Nov.	Dec.–Feb.	
Time of pruning											
Spring (T_1)		6.19 ± 0.15c	5.63 ± 0.14a	5.93 ± 0.16	6.18 ± 0.15c	5.88 ± 0.14b	78.34 ± 1.87c	73.70 ± 1.95	75.74 ± 2.09a	76.74 ± 2.02c	75.40 ± 1.98b
Monsoon (T_2)		6.51 ± 0.16b	5.33 ± 0.13b	6.03 ± 0.16	6.52 ± 0.13b	6.10 ± 0.14b	81.75 ± 1.45b	75.82 ± 2.04	72.33 ± 1.38b	82.63 ± 1.21b	77.62 ± 1.33b
Autumn (T_3)		7.10 ± 0.16a	5.31 ± 0.15b	5.93 ± 0.19	6.87 ± 0.14a	6.41 ± 0.16a	86.88 ± 1.42a	74.73 ± 1.95	73.72 ± 1.43 ab	85.44 ± 1.60a	81.26 ± 1.53a
Degree of pruning											
0 cm (L_1)		6.04 ± 0.14c	5.18 ± 0.10b	5.56 ± 0.17b	6.00 ± 0.10c	5.55 ± 0.13c	75.01 ± 1.64c	69.50 ± 2.14b	70.95 ± 1.60b	74.73 ± 1.41c	71.59 ± 1.75c
15 cm (L_2)		6.57 ± 0.17b	5.42 ± 0.16ab	6.02 ± 0.14a	6.45 ± 0.17b	6.16 ± 0.17b	81.74 ± 1.69b	74.72 ± 1.94a	73.49 ± 1.52 ab	80.05 ± 2.05b	77.77 ± 1.75b
30 cm (L_3)		6.88 ± 0.16a	5.59 ± 0.15a	6.17 ± 0.18a	6.84 ± 0.14a	6.43 ± 0.14a	86.15 ± 1.37a	77.61 ± 1.72a	75.44 ± 1.58a	85.62 ± 1.77a	81.63 ± 1.52a
45 cm (L_4)		6.91 ± 0.16a	5.51 ± 0.14a	6.12 ± 0.18a	6.79 ± 0.15a	6.37 ± 0.15 ab	86.39 ± 1.61a	77.18 ± 2.12a	75.84 ± 1.82a	86.02 ± 1.20a	81.39 ± 1.44a
Time of pruning × Degree of pruning											
T_1	L_1	6.03 ± 0.19d	5.25 ± 0.10	5.56 ± 0.15	5.96 ± 0.16e	5.57 ± 0.13	75.00 ± 2.22e	69.58 ± 1.94	71.16 ± 1.88	74.26 ± 1.98d	71.58 ± 1.92e
	L_2	6.13 ± 0.14d	5.62 ± 0.21	5.95 ± 0.14	6.09 ± 0.17de	5.85 ± 0.17	77.21 ± 1.90de	72.71 ± 2.20	74.88 ± 2.89	75.34 ± 2.03cd	74.30 ± 2.42de
	L_3	6.31 ± 0.18d	5.88 ± 0.10	6.09 ± 0.18	6.34 ± 0.12de	6.06 ± 0.12	80.13 ± 1.56d	75.97 ± 2.14	78.79 ± 1.76	78.53 ± 2.00cd	77.78 ± 1.84b-d
	L_4	6.27 ± 0.09cd	5.78 ± 0.14	6.13 ± 0.16	6.32 ± 0.15de	6.04 ± 0.15	81.01 ± 1.79d	76.52 ± 1.53	78.12 ± 1.84	78.84 ± 2.07cd	77.94 ± 1.74b-d
T_2	L_1	6.04 ± 0.10d	5.20 ± 0.08	5.55 ± 0.10	5.97 ± 0.04e	5.56 ± 0.04	75.08 ± 0.78e	69.18 ± 1.35	71.06 ± 0.89	74.24 ± 0.85d	71.44 ± 1.03e
	L_2	6.36 ± 0.16cd	5.41 ± 0.12	6.14 ± 0.18	6.44 ± 0.17cd	6.12 ± 0.17	79.00 ± 1.45de	77.07 ± 2.28	71.76 ± 0.97	79.56 ± 2.09c	76.33 ± 1.49c-e
	L_3	6.77 ± 0.16bc	5.42 ± 0.21	6.27 ± 0.19	6.88 ± 0.16a-c	6.39 ± 0.16	86.16 ± 1.51c	79.00 ± 1.93	72.73 ± 1.83	87.60 ± 1.74 ab	81.25 ± 1.59a-c
	L_4	6.87 ± 0.21b	5.29 ± 0.11	6.18 ± 0.20	6.81 ± 0.16bc	6.32 ± 0.16	86.76 ± 2.07bc	78.04 ± 2.61	73.77 ± 1.83	89.14 ± 0.14 ab	81.47 ± 1.22ab
T_3	L_1	6.06 ± 0.14d	5.09 ± 0.12	5.57 ± 0.28	6.07 ± 0.11de	5.53 ± 0.11	74.93 ± 1.93e	69.73 ± 3.12	70.63 ± 2.04	75.69 ± 1.41cd	71.73 ± 2.30e
	L_2	7.20 ± 0.21ab	5.23 ± 0.13	5.96 ± 0.12	6.83 ± 0.16bc	6.52 ± 0.16	89.01 ± 1.73a-c	74.37 ± 1.34	73.82 ± 0.71	85.26 ± 2.02b	82.69 ± 1.35ab
	L_3	7.57 ± 0.14a	5.46 ± 0.15	6.14 ± 0.18	7.31 ± 0.15a	6.83 ± 0.15	92.17 ± 1.03a	77.86 ± 1.11	74.80 ± 1.16	90.74 ± 1.58a	85.85 ± 1.13a
	L_4	7.59 ± 0.17a	5.47 ± 0.18	6.05 ± 0.19	7.24 ± 0.14ab	6.74 ± 0.14	91.41 ± 0.98 ab	76.97 ± 2.22	75.63 ± 1.79	90.07 ± 1.39ab	84.78 ± 1.36a

Values in the cells are means ± standard errors of three replications. Different letters within the column indicate statistical differences among the treatments according to LSD at $p < 0.05$.

statistically maximum and minimum TS measurement was observed 7.31 % in T_3L_3 and 5.96 % in T_1L_1, respectively. Eventually, the mean TS content in fruit over the year was calculated as greater in T_3L_3 (6.83 %) and lower in T_3L_1 (5.53 %) (Table 4).

4.14. Vitamin C (VC)

Autumn pruning had maximum vitamin C in March–May (86.88 mg 100 g^{-1}) and December–February (85.44 mg 100 g^{-1}) quarters, whereas minimum VC content was observed in spring pruning (78.34 mg 100 g^{-1} and 76.74 mg 100 g^{-1}, respectively). In September–November quarter, superior VC value was noted in spring pruning (75.74 mg 100 g^{-1}) having statistical parity with autumn pruning (74.73 mg 100 g^{-1}), while inferior VC content was obtained from monsoon pruning (72.33 mg 100 g^{-1}). Thereby, yearly mean VC content was found the highest in autumn pruning (81.26 mg 100 g^{-1}) as compared to the lowest in spring pruning (75.40 mg 100 g^{-1}) (Table 4). Meanwhile, 30 cm and 45 cm pruning levels had statistical parity for superior VC contents, and control (0 cm) pruning had inferior VC contents in fruits throughout the year. Among the interactions, VC contents non-significantly varied in June–August and September–November periods. At March–May and December–February trimesters, the greatest VC content was exhibited by T_3L_3 (92.17 mg 100 g^{-1} and 90.74 mg 100 g^{-1}, respectively) having statistical uniformity with T_3L_2 and T_3L_4 treatments at March–May period and with T_2L_3, T_2L_4 and T_3L_4 interactions at December–February period. Overall, the mean yearly vitamin C content in fruits was estimated statistically superior in T_3L_3 (85.85 mg 100 g^{-1}) exhibiting statistical parity with T_2L_3, T_2L_4, T_3L_2, and T_3L_4 interactions. Meanwhile, inferior VC content was registered in T_2L_1 (71.44 mg 100 g^{-1}) being statistically at par with T_1L_1, T_1L_2,

T_2L_1, T_2L_2, and T_3L_1 combinations (Table 4).

4.15. Fruit specific gravity (SG)

Plants pruned in autumn produced fruits having statistically superior specific gravity at both March–May (0.930 g mL^{-1}) and December–February (0.916 g mL^{-1}) quarters, while fruit specific gravity at those periods was estimated the least in spring pruning treatment (0.844 g mL^{-1} and 0.820 g mL^{-1}, respectively). Spring pruning resulted in the highest fruit specific gravity in June–August trimester (0.838 g mL^{-1}), alternately the lowest fruit SG at that period was observed in monsoon pruning (0.793 g mL^{-1}). Fruit SG in September–November quarter was found 0.830, 0.856, and 0.841 g mL^{-1} in spring, monsoon, and autumn pruning, respectively. Yearly average fruit-specific gravity was then recorded as maximum in autumn pruning (0.886 g mL^{-1}) having statistical similarity with monsoon pruning (0.859 g mL^{-1}) (Fig. 5A). In addition to that, fruits of 45 cm pruning treatment had statistically maximum SG at March–May (0.932 g mL^{-1}), June–August (0.84 g mL^{-1}), and December–February (0.929 g mL^{-1}) trimesters. Specific gravity in September–November was governed by 30 cm shoot pruning (0.877 g mL^{-1}). Statistical similarity between 30 cm and 45 cm pruning was noted for higher fruit SG. Consequently, fruit specific gravity was registered the utmost in 30 cm pruning treatment (0.899 g mL^{-1}) being statistically alike with 45 cm pruning (0.898 g mL^{-1}). Quarterly as well as yearly mean SG of guava fruits, on the contrary, was the least in no pruning (Fig. 5B). Being varied significantly fruit SG at March–May and December–February quarters was assessed maximum in T_3L_3 (0.987 g mL^{-1}) and T_2L_4 (0.977 g mL^{-1}), respectively. The specific gravity of fruits in June–August and September–November varied non-significantly among the treatment combinations from 0.780 to 0.876 g mL^{-1} and 0.894 g mL^{-1} to 0.775 g mL^{-1}, respectively. Resultantly, yearly mean fruit specific gravity was noted as the highest in T_3L_3 interaction (0.932 g mL^{-1}) and the lowest but same in T_1L_1 and T_2L_1 combinations (0.785 g mL^{-1}) (Supplementary Table 3).

4.16. Quarterly variation in fruit quality traits

Irrespective of treatments, over all fruit physiochemical attributes exhibited significant variations ($p < 0.05$) in the four quarters of the year (Table 5). The highest total soluble solids (TSS) content was noted in Q_1 duration (9.31 %) having statistical parity with that of Q_4 trimester (9.92 %). Minimum TSS was registered in the Q_2 period (7.43 %), followed by the Q_3 session (8.34 %). Titratable acidity (TA) was observed the best in Q_2 timester (0.345 %) and least in Q_4 period (0.247 %) showing similarity with the Q_1 duration. Total sugar content, vitamin C content, and fruit-specific gravity of guava were determined the highest in Q_1 timester (6.60 %, 82.32 mg 100 $g^{-1,}$ and 0.885 g mL^{-1}, respectively), followed by the Q_4 period. In contrast, fruits harvested during the Q_2 period had minimum total sugar (5.43 %) and specific gravity (0.815 g mL^{-1}), followed by Q_3 duration and vice-versa for vitamin C content in fruits (Table 5).

5. Discussion

Pruning is an age-old intercultural operation, practiced especially in fruit crops not only to remove the old, diseased, and unhealthy branches or shoot tips but also to enhance healthy re-growth for the following season [28,29]. It is the mechanical removal of live plant parts such as leaves, shoots, shoot tips, branches, or even flowers and fruits to enhance juvenility, maintain healthy and uniform plant structure, and obtain sustainable economic yield [22,30]. Ali [31] also suggested pruning as one of the key cultural management practices for long-lasting orchard production in guava. The present study exhibited that pruning at varied seasons (spring, monsoon, and autumn) by different levels (control or 0 cm, 15 cm, 30 cm, and 45 cm) induced new shoots in guava; therefore more number of leaves, flowers and fruits arose than non-pruned plants at sub-tropical conditions having unstable and fluctuating temperature and humidity regimes. It is reported that floral buds emerge in new vigorous sprouts from continuous flushes of guava and pruning facilitates the development of new shoots [32]. Zivdar et al. [33] noted that pruning operation affects the vegetative and floral behavior of many fruit crops by manipulating the time of flush, maturity, and physiology. Due to the pruning of old and mature shoots, plant physiological functions force hormones and carbohydrates to accumulate in the cut branches for faster emergence of new shoots and leaves [34,35]. In addition, pruning creates wounds in the branches. In response to wound healing, food materials and

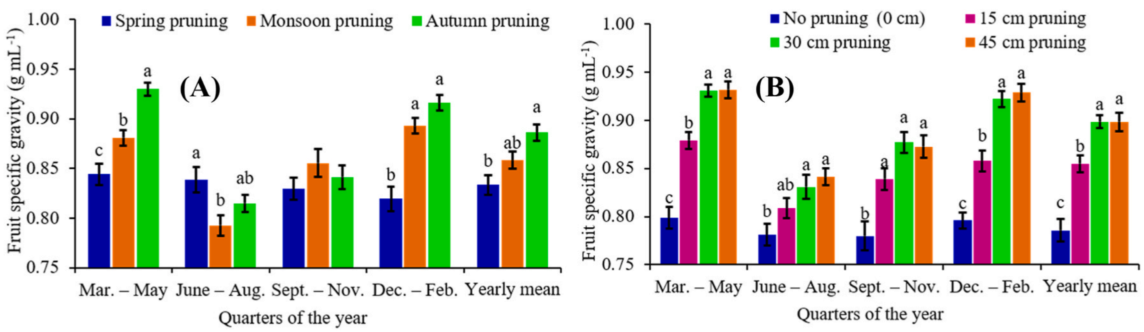

Fig. 5. Variations in the specific gravity of guava as influenced by pruning time (A) and pruning level (B). Vertical bars on the top of the columns represent the standard errors of means of three replicates. Different letters indicate the statistical differences among the treatments at $p < 0.05$.

Table 5
Quarter-based variations in fruit biochemical properties in guava.

Quarters of year	Total soluble solids (%)	Titratable acidity (%)	Total sugar (%)	Vitamin C (mg 100 g^{-1})	Specific gravity (g mL^{-1})
Q_1	9.31 ± 0.02a	0.253 ± 0.0c	6.60 ± 0.03a	82.32 ± 0.15a	0.885 ± 0.0a
Q_2	7.43 ± 0.03c	0.345 ± 0.0a	5.43 ± 0.01d	74.75 ± 0.06c	0.815 ± 0.0d
Q_3	8.34 ± 0.02b	0.309 ± 0.0b	5.97 ± 0.02c	73.93 ± 0.13d	0.842 ± 0.0c
Q_4	9.29 ± 0.01a	0.247 ± 0.0c	6.52 ± 0.00b	81.61 ± 0.13b	0.876 ± 0.0b

Values in the cells are means ± standard errors of three replications. Different letters within the column indicate statistical differences among the treatments according to LSD at $p < 0.05$. Here, Q_1, Q_2, Q_3, and Q_4 denote the four quarters of the year namely March–May, June–August, September–November, and December–February, respectively.

growth-promoting phytohormones 'gibberellins, cytokinins' translocate acropetally resulting in new vegetative bud emergence [36]. Aside from this. Bagchi et al. [37] confirmed that pruning and bending of branches stimulate molecular changes in guava which resulted in an increased number of shoots and leaves with enhanced levels of polyphenol oxidase, catalase, and peroxidase enzymes as well as lipid, proline and tryptophan levels in shoots, but significantly decreased levels of phenolics as compared to control plants. An increased number of leaves promoted the photosynthetic area resulting in higher carbohydrate assimilates in new shoots which in turn accelerated the floral bud induction in pruning-operated plants. Similarly, Vosnjak et al. [38] investigated that pruning techniques regulate the sugar contents (sorbitol and fructose) in the branches of cherry for the development of flowering buds.

The study revealed that different pruning times exhibited distinguishable variations in quarterly growth, flowering, yield, and fruit quality attributes in guava, though yearly variations weren't prominent in some cases. Although the yearly total number of new shoots, new-shoot leaves, and flowers plant^{-1} were statistically similar, the statistical superiority for shoot, leaf, and flower numbers was recorded at the immediate post-pruning quarters which might be due to the instant plant response as a result of hormone functions and carbon metabolism [34,39]. Except for monsoon pruning, the intensity of shoot, leaf, and flower development gradually slowed down. The seasonal variations in weather attributes might have overcome the pruning time effect on this aspect of vegetative growth and flowering. Temperature, humidity, and light are the key environmental factors regulating a variety of plant physiological processes including photosynthesis, enzyme activation, uptake of mineral elements, and plant morphology and phenology [40–42]. It was observed in the present experiment that pruning in the monsoon and autumn (June to October) seasons, the guava plants experienced very low temperatures, waning humidity, and almost no precipitation from December to February (Fig. 1). Guava is a tropical fruit, and its vegetative growth and emergence of new flushes became diminished at minimal weather qualities resulting in reduced levels of shoot, leaf, and floral bud development [43]. With the occurrence of favorable weather conditions at the onset of spring, the production of new shoots, leaves, and floral buds started in plenty from March. Again, guava possesses an incomplete 'terminal bearing habit' where flowering occurs in large numbers with leafy shoots in summer and monsoon seasons compared to winter (December-February) [44,45]. Besides, new shoots after pruning favored the floral bud emergence in the following quarters. Pruning is the prime cultural management to maintain the carbon to nitrogen ratio (C:N ratio) in the plants by curtailing excessive vegetation. The balance in C:N ratio ensures the subsequent reproductive development in plants as occurred here in guava [31]. Food reserves in the winter stimulated the earliest sprouting of vegetative and reproductive buds from spring-pruned plants [18]. Bose et al. [45] and Sahoo et al. [46] also stated early flowering in the spring season in comparison to the rainy and winter seasons. High humidity, excessive rains, and improper sunshine hours led to poor flowering in monsoon pruning.

Fruit yield and quality in plants depend on proper pollination, fertilization, fruit set, fruit retention, and weather conditions during the fruit development stages [47,48]. Climatic factors, such as temperature, relative humidity, vapor pressure deficit, solar radiation, rain, and wind are the factors related to seasonal variations [49] that influence the fruit yield and quality of guava. Though the total number of flowers in guava didn't vary after pruning at different times, the total number of fruits and fruit yield per plant was noticed significantly maximum in spring pruning. In addition, autumn pruning resulted in the highest fruit set to show statistical parity with spring for fruiting and yield plant^{-1} year^{-1} in guava. Contrarily, monsoon pruning exhibited minimum fruit set to get inferior fruit yield over the year. Heavy rain and overcast sky prevailed from June to October (Fig. 1) might have accelerated the natural drop of fruits at their early developmental stages [50]. Pantelidis et al. [51] also stated that consecutive wet days and extensive precipitation at the flowering and early fruit growth stages impair fruit setting and cause premature fruit drop in peaches as occurred here for monsoon pruning in guava. Several investigations [52–54] also addressed that high humidity coupled with warm temperatures and cloudy conditions are congenial environments for the pests and diseases of guava. These insects and pathogens might have triggered the fruit-dropping of guava in the present experiment. Tamaki et al. [55] found that the pollen tube germination rate in papaya slows down from July to September duration than the spring and autumn periods. Such a phenomenon might have occurred in the present experiment for monsoon pruning leading to poor fertilization and fruit set in guava. On the other hand, flowers and fruits of spring and autumn pruned plants enjoyed complacent weather attributes to produce good yield. More interestingly, fruit availability i.e., harvesting time was greatly influenced by the time of pruning where spring pruning led the rainy season (June–November) yield, while autumn pruning had maximum marketable fruits in the winter and dry months (December–May). Depending on the seasonal weather variations, land topography, management practices, and elevation from the sea level, guava requires 100–180 days from flowering to harvesting [56–58]. Therefore, profuse flowering in the March–May and June–August periods resulted in the greatest yield in the June–August and September–November quarters in spring pruning. Whereas fruits developed from flowers of autumn pruning became ready to harvest in December–February and March–May. Summer being the main flowering season of guava, a considerable yield was also obtained in the rainy season from autumn-pruned plants. Widyastuti et al. [59] and Patial et al. [60] also observed that late monsoon pruning produced good guava yield in both winter and summer seasons.

In addition, a comprehensive impact on quarterly and mean yearly changes in fruit biochemical properties was exerted by the timing of pruning. Autumn pruning was the best, while spring and monsoon pruning were inferior for mean yearly TSS, titratable acidity, total sugar, vitamin C, and specific gravity of fruit. Regarding the quarterly observations, autumn pruning exhibited distinguishably prominent fruit quality in winter and dry periods (December–February and March–May). Whereas postharvest qualities of fruits during the rainy season (June–August and September–November) weren't affected by pruning times. Furthermore, regardless of pruning techniques, fruit quality traits of guava were further noted better in the dry quarters than in the wet quarters. Silva et al. [58] also investigated that pruning in August and September gave fruits with promising fruit physical properties in guava 'Paluma'. Further, Kavvadias et al. [61] and Cruz et al. [62] demonstrated seasonal variations in plant mineral nutrition availability due to weather fluctuations which ultimately governed the fruit quality indices in different seasons. Moura et al. [63] investigated the seasonal influence on productivity and fruit quality of *Annona squamosa* and observed that dry-season harvests retained superior quality over rainy-season fruits. The low sunshine hours and heavy rains during the July–September period could deplete the soil nutrients beyond the reach of the plant roots resulting in low photosynthate accumulation by leaves. Besides, continuous rain and high humidity might damage the delicate feeding roots in guava that hamper nutrient uptake by plants resulting in inferior quality of the fruit during June–August and September–November. Whereas, December–February and March–May were characterized by minimal or no rain and long sunshine hours for higher photosynthesis to enhance the fruit quality. Sarker et al. [16] demonstrated that heavy and uneven rain resulted in inferior quality, insipid, watery, insect-infested fruits of poor market life. In contrast, winter and dry season fruits are very pleasant in taste and excellent in quality with high market demand [17]. Moreover, the presence of active mature leaves and the maximum source-to-sink ratio in the winter and dry quarters in autumn pruned plants helped in producing maximum food materials in leaves and its transfer to the fruits augmented the fruit biochemical attributes. As spring pruned plants yielded maximum harvest during June–August and September–November periods, the fruits passed a long spell of rain and a humid environment to produce inferior quality fruits. The present findings are in agreement with that of Sahar and Abdel-Hameed [15] who harvested good quality winter guava from plants that were pruned in July compared to May and Monsoon pruning. Similarly, Patial et al. [60] and Satya et al. [64] found out late summer pruning effectively promoted the yield and quality of guava over early season pruning under sub-tropical conditions.

The present study further manifested that moderate pruning i.e., pruning by 30 cm shoot tip removal produced profuse shoots and leaves compared to those of other pruning levels. The same treatment also resulted in the highest number of flowers and fruits for securing the topmost yield, while 45 cm pruning downgraded shoot and leaf production, followed by less flowering, fruiting, and yield compared to that of 30 cm pruning. However, fruit biochemical traits like total soluble solids, total sugar, vitamin C, and fruit-specific gravity were estimated as statistically identical in both 30 cm and 45 cm pruning levels. It can be explained that plants had enough branch length at the base below 30 cm shoot-tip to generate a large number of new shoots and leaves after pruning compared to 45 cm pruning degrees. Higher shoot and leaf growth might have occurred due to alteration in carbon partitioning in response to shoot removal and hormonal changes at the post-pruning stages [39]. Ali [31] enunciated that proper pruning preserves adequate food reserves for vegetative flourishment in the pruned guava plants. Reports expressed that different pruning techniques account for various light interception (LI) levels and light distribution pattern across the plant canopy [65]. Stephan et al. [66] further pointed out that training and pruning have an impact on the growth, location, and crotch angle of branches, which affects their capacity to intercept light and, in turn, affects fruit quality and quantity as occurred in case of 30 cm pruning at the present experiment. However, excess or hard pruning is detrimental to producing optimum yield and sometimes can cause total death of the plants [32]. Meena et al. [67] noted that plants under 30–45 cm shoot-tip pruning got a higher number of leaves, flowers, and fruits round the year compared to 15 and 60 cm pruning in guava cv. Lalit. Likely, Adhikari and Kandel [18] measured higher yield with excellent post-harvest fruit qualities in guava cv. L-49 when 20–30 cm pruning was performed. Moreover, Santhoshkumar et al. [68] observed that shoot pruning and branch pinching induce new growth and flowering, and promote fruiting characteristics of guava. Bhagawati et al. [69] argued that appropriate pruning has a rejuvenating effect on plants because it improves light absorption, which improves photosynthetic rate, nutrient and water supplies, and crop quality. Several other studies also reported yield and fruit quality improvement in guava through regulated pruning [19,21,70].

In short, pruning at different times by different lengths modified the active shoot and leaf growth and carbohydrate synthesis which consequently altered the flowering, fruiting, and fruit quality in different quarters of the year. Presence of the abundant number of growing leaves and congenial weather conditions during the post-pruning flowering and fruit developmental phases, autumn pruning produced maximum yield in the fruit-scarce lean period (December to May) having superior fruit quality along with optimum annual yield.

6. Conclusion

Shoot-tip pruning of guava in the spring, monsoon, and autumn by 0, 15, 30, and 45 cm resulted notable change in growth, yield, and fruit quality of guava. Pruning by 30 cm branch removal exhibited superiority over other treatments for all the aspects of growth, development, and quality of guava throughout the year. Interestingly, pruning in different season produced uniform number of flowers in a year, notwithstanding flowering variations in different quarters accompanied by seasonal weather fluctuations influenced the fruit set index and quarterly yield. It, hence, resulted in the similar highest yield in spring and autumn pruning. Nevertheless, autumn pruning produced maximum harvestable fruits with superior quality in the fruit scare off-season of December to May period. Consequently, 30 cm branch pruning in autumn can be suggested to obtain good quality year-round harvests in guava.

Further in-depth study on the utilization and interception of light after pruning as well as dry and fresh weight, nutrient content, and hormonal changes in the pruned branches/plants can be performed for longer period to draw precise conclusion for tropical fruit crop management, which will have substantial contribution in using the sustainable technology by the stakeholders.

Ethical statement

Guava var. *BARI Peyara-2* (registered guava variety of Bangladesh released by the Bangladesh Agricultural Research Institute) was used as plant material and pruning was performed as per objectives of the study. The field operations in this experiment were carried out following guidelines and recommendations of "Biosafety Guidelines of Bangladesh" published by Ministry of Environment and Forest, Government of regularly monitored and supervised under the guidelines of BARI. The authors considered all sorts of ethical issues regarding the use of plant materials.

Data availability statement

Data will be made available on request.

CRediT authorship contribution statement

Joydeb Gomasta: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Babul Chandra Sarker:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Conceptualization. **Mohammad Amdadul Haque:** Writing – original draft, Formal analysis, Data curation. **Asma Anwari:** Writing – review & editing, Data curation. **Satyen Mondal:** Writing – review & editing, Data curation. **Md. Sorof Uddin:** Writing – review & editing, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e30064.

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