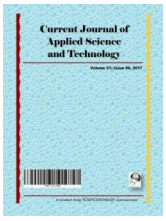

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Effect of Pruning on Productivity of Guava under High Density Plantation – A Review

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Authors' contributions

This work was carried out in collaboration between all authors. Author HS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SB and Vijay managed the analyses of the study. Author PS managed the literature searches. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The productivity of guava is presently much below the productive potential, due to traditional practices and prevalence of old and unproductive orchards with declining yield efficiency. Moreover, large trees take several years before they come into bearing and overall cost of production per unit area is further increased. The hi-tech and Innovative methods which include high planting density have been identified to increase guava production in India in order to be competitive in world market. The response of guava to training and pruning for canopy modification is well known. It is one of the most suitable for high planting density, as it bears on current season's growth and responds to pruning. Modifications in pruning and training techniques influence plant spacing and production decision. Similarly, unpruned tall and crowded guava trees pose a number of problems while carrying out various cultural operations. Guava has a higher proportion of 'shade' to 'sun' leaves and their leaves are found photosynthetically inactive under deeper shade and act as unproductive sink. Therefore, vegetative growth, fruit yield and quality are functions of light interception and translocation of light energy into chemical energy. Quality fruit is function of

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absorption of light and light is directly proportional to the yield of fruit trees. In the present, high-density plantation with managed canopies is the need of the hour to achieve high productivity per unit area.

Keywords: Canopy management; high-density plantation; pruning; training.

1. INTRODUCTION

1.1 Present Status

Guava (*Psidium guajava* L.) the "apple of tropics" is an important fruit crop which is successfully grown over a range of climatic conditions due to its wide adaptability. It belongs to family Myrtaceae which contains about 150 species Bose and Mitra [1] and has the recognition of being the most widely cultivated species of this family. It is believed to have originated in an area extending from Southern Mexico through parts of Central America. Today guava is grown throughout the tropics and subtropics. The major guava producing countries are India, Brazil, Mexico and South Africa. In India guava cultivation commenced from 17th century and present ranks fifth in position after mango, banana, citrus and apple in terms of area, but fourth in production after mango, banana and citrus. In India, guava occupies an area of 2.62 lakh hectares with annual production of 36.48 lakh tonnes. In Haryana, the area under this crop is 12000 hectares with a total production of 185 600 tonnes and productivity of 15.4 Mt/ha [2].

1.2 Nutritionally Valuable and Remunerative Crop

Guava trees are vigorous bearing roundish ovate fruits which weigh 90-140 g. The fruit of guava contains 36-50 kcal energy, 77-86 g water, 200-300 mg ascorbic acid, 200-400 I.U. carotene per 100 g edible portion. It also contains a fair source of vitamin A, riboflavin, thiamine and minerals like calcium, phosphorus and iron. Furthermore, guava is processed commercially into jam, jellies and other products. Guava is considered as one of the nutritionally valuable and remunerative fruit crops. It excels most other fruit crops in productivity, hardiness, adaptability and nutritive value. Guava is not only a wholesome fruit but it is a rich source of vitamin-C and pectin [3]. Guava also contains antioxidant pigments, carotenoids and polyphenols giving them relatively high dietary antioxidant value among tree foods [4,5,6].

1.3 Importance of Pruning

Guava bears on current season's growth and flowers appear in axils of leaves, therefore, it responds well to pruning. There are three distinct flowering seasons in guava namely, Spring (*Ambe bahar*), Rainy (*Mrig bahar*) and Autumn (*Hastha bahar*) with corresponding harvesting period in rainy, winter and spring, respectively. After 8-10 years of age, guava trees show a considerable decline in yield with sub-optimal fruit quality, owing to vigorous vegetative growth and frequent intermingling of the branches, particularly on the lower half of the tree, ultimately leading to unfruitfulness, as the fruitful bud become blind. Such unproductive trees can be made to bear a profitable crop for more years by judicious pruning. Pruning will not only restore the balance between shoot and root system but will also maintain growth and vigour of shoots by allowing only fewer growing points to growing vigorously. Large trees take several years before they come into bearing and overall cost of production per unit area is increased. Hence, there is need to improve the existing planting system and to manipulate tree growth using canopy management to control tree growth patterns, tree shape and maintaining high fruit production of desired size and quality [7].

1.4 Need of High-density Plantation (HDP) Guava

Due to large tree canopy, the traditional system of cultivation has often posed problems in obtaining desired fruit productivity per unit area. Therefore, there is need of changing production system in guava by manipulating its natural plant canopies. Currently, there is a worldwide trend of higher density planting to control tree size and maintain desired architecture for higher productivity. Better light interception and improved microclimatic conditions in the orchard and within the plant canopy not only improved the productivity but improve the quality of fruits and reduce the stress of pests and disease. So, that the high density or meadow recharging facilitates enhance production and quality of fruits by managing the plant canopies in different ways. There is a shift in farmers' insight from

production to productivity and profitability which can be achieved through high density planting. Recently, there is a trend to plant fruit trees at closer spacing leading to high density or meadow orchard. Higher and quality production is achieved from densely planted orchards judicious canopy management and the adoption of suitable tree training systems [8].

1.5 Applicability of the Present Study

Pruning and high density planting in most of the temperate fruit for higher production of quality fruit per unit area has already been taken a lead in major fruit growing areas. However, in tropical and sub tropical fruit the concept of high density planting is gaining a momentum with the introduction of growth retardants, pruning and training techniques. High density planting orchard may be exploited by managing the plant canopies through standardizing the training, techniques. The work carried out by various scientists on pruning is reviewed under different sub heads.

2. GROWTH CHARACTERS

2.1 Number of Sprouts per Shoot

The fruit production is bound to increase with the increase in the number of new shoots produced, since the new shoots are the potent fruit bearing organs in guava. Lotter [9] observed that, in guava with the 25 per cent pruning intensity, large number of lateral shoots encouraged. Hence, their ultimate growth was less as compared with the severely pruned trees which had left only limited shoots. Medina et al. [10] studied the influence of pruning in July and Paclobutrazol application (to soil or foliage) on growth, flowering, yield and fruit size in young mango trees of cultivar Tommy Atkins, scientists reported that pruning the trees to 2.0, 2.5 and 3.0 m height increased the shoot number compared to the unpruned trees. Dubey et al. [11] conducted an experiment to study the effect of severity of pruning (0%, 25%, 50%, 75% and 100%) on number of sprouts in *cv.* Allahabad Safeda. The maximum number of shoots emerged after pruning (lateral shoots) were recorded with 25 per cent pruning intensity and number of shoots decreased with the increasing severity of pruning. Yeshitela et al. [12] A trial was conducted out on the effects of various pruning treatments in two mango cultivars (Keitt and Tommy Atkins) and observed that trees received the treatment of cut back terminal shoots, bore fruit of the previous season (postharvest pruning) resulted in the maximum number of leaves per flush in both cultivars i.e. 20.44 in 'Tommy Atkins' and 14 in 'Keitt'. Saini [13] observed that removing of current season growth up to 45cm level resulted in maximum growth in terms of number of sprouts. Researchers observed that pruning of guava cv. Allahabad Safeda under high density planting with three pruning intensities *i.e.* leaving 10, 20 and 30 cm from base of the shoot and retaining 30, 40 and 50 fruits per tree, resulted in maximum cumulative length of new shoots. Pruning intensity of 30cm has increased the number of vegetative buds per pruned shoot and number of new shoots per pruned shoot along with early harvesting at color turning stage [14].

2.2 Shoot Length

Pruning seems to play an important role in controlling the size and number of new shoots produced in the pruned trees. Bajpai et.al., [15] conducted an experiment on well established 15-years-old guava trees of Allahabad Safeda comprised of no pruning, 30 cm, 60 cm, and 100 cm. The maximum shoot length (19.73 cm) was recorded in severely pruned tress and minimum (2.51 cm) in unpruned trees. Similar results have been reported by [16,17,18] in Sardar cv. of guava. Bajwa and Sharma [19] reported that the increase in length of new branches was directly proportional to the severity of pruning in ber. Similar results have also been noticed by [20] and [21] in cv. Umran and in cv. Pewandi and Karaka of ber, respectively, that different intensity of pruning had virtual effect on length of shoots. Singh and Chauhan [22] studied the effect of different pruning intensities (light, medium, heavy, 700-750 nodes/tree) in July Elberta peach. The heavily pruned tree had significantly longer shoots (42.83 cm and 42.02 cm) than other pruning treatments during both the years. Researchers conducted an experiment to evaluate the response of pruning intensity on growth and yield of ber cv. Banarasi Karaka. The shoot length was maximum with 60% pruning on previous season growth [23].

2.3 Plant Height

Most of the published results suggest that plant height is decreased with the increase in severity of pruning. An experiment was conducted to study the effect of pruning date (10, 20, and 30 April) and level (0, 10, 20 and 30 cm) on the canopy, girth and height of guava cv. Sardar.

The canopy volume increased with the increases in pruning level and tree height declined with the increase in the severity of pruning. Pruning date did not significantly affect tree canopy volume, girth and height [24]. Kumar and Rattanpal [25] studied the effect of pruning in guava planted at different spacing under Punjab conditions. The mean tree height was found maximum (5.6 m) in control trees of 6x6m spacing and was minimum (4.7 m) in pruning by removal of half the vegetative growth at spacing of 6x4 m. An experiment was conducted to study the Influence of training systems on growth, yield and fruit quality of pomegranate 'kandhari'. Taller plants were observed in 30 cm trunk height trained plants [26]. An experiment was conducted to study the response of varying rejuvenation periods of an old guava orchard (cv. Allahabad Safeda). Fifteen-year-old guava plants were severely pruned leaving only four scaffold branches per tree at monthly interval from April to June, 2008. The tree height was found maximum in control and minimum due to rejuvenation pruning during May [27]. Pratibha et.al., [28] conducted an experiment to study the effect of pruning and planting systems on growth, flowering, fruiting and yield of guava cv. Sardar. Results revealed that regardless of planting systems, one leaf pair pruning significantly decreased the annual increment in plant height as compared to control. Annual increase in tree height was highest in double-hedge row system.

2.4 Plant Spread

In mango cv. Dashehari, Lal and Mishra [29] recorded greater canopy spread in unpruned trees than in pruned trees. Researchers studied the effect of pruning in guava planted at different spacing under Punjab conditions, they observed that the mean tree spread was found maximum (6.5 m) in control trees of 6x6m spacing and was minimum (4.8 m) in pruning by removal of half the vegetative growth at spacing of 6x4 m [25]. Singh et al. [27] conducted an experiment to study the response of varying rejuvenation periods of an old guava orchard (cv. Allahabad Safeda). Fifteen-year-old guava plants were severely pruned leaving only four scaffold branches per tree at monthly interval from April to June, 2008. They found that the tree spread was affected significantly by different periods of rejuvenation. The tree spread was found maximum in June and minimum in May. Scientists conducted an experiment to study the effect of pruning and planting systems on growth, flowering, fruiting and yield of guava cv. Sardar. Tree spread was highest in square system of planting with one leaf pair pruning during both the years [28].

2.5 Tree Volume

Rabe [30] reported that pruning is an effective measure to control tree size in citrus trees. Kaur and Dhaliwal [31] registered the highest net increment in tree volume of 20.87 m^3 over control with 30 cm pruning level in guava. Kumar and Rattanpal [25] studied the effect of pruning in guava planted at different spacing under Punjab conditions. Severity of pruning resulted in decrease of tree volume. The mean tree canopy was maximum (118.8 m^3) in control trees of 6 x 6 m spacing and was minimum (57.1 m^3) under pruning treatment by removal of ½ vegetative growth in 6 x 4 m spacing. Researchers conducted an experiment to study the response of varying rejuvenation periods of an old Guava orchard (cv. Allahabad Safeda). Pruning resulted in decrease of tree canopy volume [27]. Pratibha et al. [28] conducted an experiment to study the effect of pruning and planting systems on growth, flowering, fruiting and yield of guava cv. Sardar. Tree volume (1.80 m^3) was highest in square system of planting with one leaf pair pruning during both the years.

3. FLOWERING AND FRUITING CHARACTERS

3.1 Flowering Intensity

Flower production is bound to increase due to pruning, as it has been pointed out by several studies. Rao and Shanmugavelu [32] bserved that mango trees of cv. Mulgoa and Banganapalli produced profuse flowering just after the pruning of terminal shoots. Meanwhile, [16] observed a reduction in flowering in case of severely pruned (25 cm) trees during both the rainy and winter season crops of guava cv. Sardar at Kodur, Andhra Pradesh. But, the mild pruning (10 cm) produced more flowers in July-August flowering flush. Lal [33] found that pruning in Guava cv. L-49 increased the number of flowers per shoot in cropping of winter season. The shoots pruned in the month of May at the level of 50% reduced maximum number of flowers per shoot. Singh et.al, [34] studied the effect of pruning dates on yield of Guava cultivars that is Allahabad Safeda and Sardar for five consecutive years. They reported pruning from April through June, enhanced the flowering percentage as compared

to pruning in February and March. Jadhav et.al, [35] noticed that number of flowers per shoot on severely pruned (60%) trees of Guava was found to be significantly more than mild pruned (30%) trees and control. Mohammed et.al, [18] noticed that maximum flowers per shoot during winter season were recorded in 60 cm pruning treatment. Mehta et al. [36] conducted an experiment to study the effect of pruning on Guava cv. Sardar under ultra high density orcharding system. Effect of different treatments on total number of flowers per plant in different season was recorded only in case of winter season 2009-10. Pruning three times a year resulted in maximum number of flowers per plant (20.13) whereas pruning to 80% of canopy in October resulted in minimum number of flowers per plant (7.72) during winter season of 2009-10. Researchers conducted an experiment to study the effect of pruning and planting systems on growth, flowering, fruiting and yield of guava cv. Sardar. Maximum number of flower buds (62.2) was found in the treatment combination of one leaf pair pruning and square system of planting [28].

3.2 Fruit Setting

Pruning has been found to improve the fruit set in many cases. Mishra and Pathak [37] reported that fruit set decreased significantly with the increase in the pruning intensity from 25 to 75% and pruning periods from March to June. In winter season there was significant increase in fruit set with the increase in level of pruning from 25 to 75%. Sahay and Singh [38] conducted an experiment on regulation of cropping in guava. The highest fruit set in the following winter was obtained with double spray of 15% Urea followed by hand deblossoming and $^{3}/_{4}$ current shoot pruning. Similar observations were recorded by [39,40,41] in Guava. Brar et al. [42] studied the effect of three pruning intensities (15, 30 and 45cm from the shoot tips and the unpruned trees as a control) on yield and quality of Guava cv. Sardar. An increasing trend in percent fruit set with an increase in pruning intensity was observed in both the seasons. Lotter and Lotter [43] found a reduction in fruit set following summer pruning in Guava. Singh [44] studied the influence of pruning intensity and pruning frequency on reproductive attributes and leaf C/N ratio in Sardar Guava. He reported an increment in fruit set with the enhanced severity of pruning and the results were not significant. Pratibha et al. [28] conducted an experiment to study the effect of pruning and planting systems on growth, flowering, fruiting and yield of guava cv. Sardar. In rainy season, the maximum fruit set (60.4%) was observed in unpruned guava plants under square system of planting and lowest fruit set (11.6%) was observed in treatment combination of one leaf pair pruning and double hedge row system of planting. However in winter season the fruit set was maximum (65.6%) in treatment combination of one leaf pair pruning and square system of planting and minimum (18.5%) in unpruned plants under double hedge row system of planting during both years.

3.3 Number of Fruits per Plant

Earlier it was believed that pruning will enhance the fruit yield in terms of number of fruits, but the contradictory reports have been received about this aspect, since different species respond differently to the pruning. Further, these responses vary with the pruning intensity.

Lal [33] found that pruning in Guava cv. L-49 increased the number of fruits per shoot in cropping of winter season. The shoots pruned in the month of May at the level of 50% reduced maximum number of fruits per shoot. Mishra and Pathak [37] reported that number of flowers of guava decreased significantly with the increase in the pruning intensity from 25 to 75% and pruning periods from March to June. In winter season there was significant increase in number of flowers (14.10) with the increase in level of pruning from 25 to 75%. Jadhav et al. [35] noticed that number of fruits per shoot on severely pruned (60%) trees of Guava was found to be significantly more than mild pruned (30%) trees and control. Mohammed et al. [18] noticed that maximum fruits per shoot during winter season were recorded in 60 cm pruning treatment. Brar et al. [42] studied the effect of three pruning intensities (15, 30 and 45 cm from the shoot tips and the unpruned trees as a control) on yield and quality of Guava cv. Sardar. The maximum number of fruits per tree (430 and 496) was recorded in the plants pruned at 15 cm level followed by unpruned trees in both winter and rainy season crop, respectively. Similarly, [45] observed that with an increase in pruning intensity number of fruits per tree was reduced. Singh [44] studied the influence of pruning intensity and pruning frequency on reproductive attributes and leaf C/N ratio in Sardar Guava and reported that 6 node pruning intensity recorded significantly higher fruit number/tree during the cropping seasons of both the years. The interaction effect of pruning intensity and pruning

frequency revealed that trees pruned to 6 nodes under regular pruning treatment recorded significantly higher fruit number per tree. Researchers conducted an experiment to study the effect of pruning and planting systems on growth, flowering, fruiting and yield of guava cv. Sardar. Maximum number of fruits per plant (487.4) was found in the treatment combination of unpruned tree with square system of planting in rainy season, while it was maximum (397.3) in treatment combination one leaf pair pruning and square system of planting in rainy season. In the 2nd year similar trend was observed [28].

3.4 Yield

Mishra and Pathak [37] reported that 50% pruning in May produced the highest fruit yield in winter crop. Jadhao et al. [46] had reported highest fruit yield of Guava cv. Sardar with single pruning 60 cm from the tip on 25th April. Singh et al. [34] studied the effect of pruning dates on yield of Guava cultivars i.e. Allahabad Safeda and Sardar for five consecutive years. The yield during winter season was increased significantly in May and June pruned trees than the unpruned trees of both the varieties. Sahay and Singh [38] conducted an experiment on regulation of cropping in guava. During winter season, the yield per plant was recorded maximum in double spray of Urea 15% followed by hand deblossoming and $^{3}/_{4}$ current shoot pruning. Singh and Dhaliwal [47] conducted an investigation on effect of different pruning levels on fruit yield and quality of Guava cv. Sardar. The maximum fruit yield of 37.9 kg and 52.3 kg/tree was obtained in 10cm pruning level during the rainy and winter season crop, respectively. Brar et al. [42] studied the effect of three pruning intensities (15, 30 and 45 cm from the shoot tips and the unpruned trees as a control) on yield and quality of Guava cv. Sardar. The maximum yield 72.2 and 82.3 kg/tree were recorded in the plants pruned at 15 cm level followed by unpruned trees in both winter and rainy season crop, respectively. Singh et al. [48] studied the effect of pruning on crop regulation of Guava cv. Allahabad Safeda. The minimum fruit yield i.e. maximum crop regulation in summer (5.82 kg/tree) was recorded in with total pruning of the flowering/fruit bearing portion of current season shoot treatment; this was followed by heading back of the current season shoots to the level of two basal leaves treatment (9.76 kg/tree), whereas, the maximum yield was recorded in case of control (84.63 kg/tree). In winter season, highest fruit yield was recorded with control (104.98 kg/tree) followed by heading back of the current season shoots to the level of two basal leaves (100.91 kg/tree).

Singh [44] studied the influence of pruning intensity and pruning frequency on reproductive attributes and leaf C/N ratio in Sardar Guava. The highest fruit yield was obtained in trees subjected to 6 node pruning intensity. Interaction between pruning intensity and pruning frequency showed that 6 node regular pruning treatment emerged as the best treatment with respect to fruit yield. Mehta et al. [36] conducted an experiment to study the effect of pruning on Guava cv. Sardar under ultra high density orcharding system. The maximum yield of summer season crop was recorded in case of pruning thrice a year to 50% of shoot length. Pruning to 80% of canopy in October resulted in the maximum yield of rainy season crop. Pruning to 60% of plant height resulted in maximum yield of winter season crop. Lakhpati et al. [14] observed that pruning of guava cv. Allahabad Safeda under high density planting with three pruning intensities *i.e.* leaving 10 cm, 20 cm and 30 cm from base of the shoot and retaining 30, 40 and 50 fruits per tree, 10 cm pruning intensity advanced the fruit yield. Pratibha et al. [28] conducted an experiment to study the effect of pruning and planting systems on growth, flowering, fruiting and yield of guava cv. Sardar and concluded that, double hedge row system of planting in Guava along with one leaf pair of pruning may be adopted to increase yield.

Kumar et al. [23] conducted an experiment to evaluate the response of pruning intensity on growth and yield of ber cv. Banarasi Karaka and reported maximum fruit yield per tree (109.19 kg) with moderate pruning (30% pruning) intensity which proved significantly superior over 10% pruning intensity and control.

4. PHYSICO-CHEMICAL ATTRIBUTES

4.1 Average fruit weight

In general, fruit weight is likely to increase with pruning. Dhaliwal and Kaur [49] conducted an experiment to ascertain the effect of pruning dates (10, 20 and 30th April) and four pruning intensities (0, 10, 20 and 30 cm) on the age of flowering shoot and fruit quality of Sardar Guava. Among the different pruning treatments, maximum fruit weight (149.66 g) was obtained with 30 cm pruning. The interaction effect between the dates and pruning intensities were

noticed to be non significant. The findings of these studies were found in consonance with that of [50,15] who also found an increase in fruit weight in Guava with a severity of pruning. Maximum fruit weight by severe pruning in ber was also observed by [51]. Singh and Dhaliwal [47] conducted an investigation on effect of different pruning levels on fruit yield and quality of Guava cv. Sardar. The highest fruit weight of 147.3 g and 153.5 g was observed in 30 cm pruning level during rainy and winter season, respectively. Mohammed et.al, [18] noticed that fruit weight was highest in 60 cm pruning treatment during rainy season and in 30 cm pruning treatment during winter season. Brar et al. [42] studied the effect of three pruning intensities (15, 30 and 45 cm) from the shoot tips and the unpruned trees as a control) on yield and quality of Guava cv. Sardar. The highest fruit weight was recorded (170.2 and 172.3 g in rainy season and winter season, respectively) from the trees pruned at 45 cm level. Singh et.al, [48] studied the effect of pruning on crop regulation of Guava cv. Allahabad Safeda. The maximum average fruit weight 145.35 g/fruit in summer season was recorded with total pruning of the flowering/fruit bearing portion of current season growth treatment followed by heading back of the current season shoots to the level of two basal leaves treatment while it was minimum in control. Mehta et al. [36] conducted an experiment to study the effect of pruning on Guava cv. Sardar under ultra high density orcharding system. The treatments did not differ significantly with respect to their effect on fruit weight of rainy season crop and winter season crop during both the years of 2010-11. During winter of 2009-10 pruning to 80 % of canopy height in May resulted in maximum average fruit weight and minimum fruit weight was recorded in case of pruning thrice a year to 50 % of shoot length. Lakhpati et al. [14] observed that pruning of guava cv. Allahabad Safeda under high planting density with three pruning intensities *i.e.* leaving 10 cm, 20 cm and 30 cm from base of the shoot and retaining 30, 40 and 50 fruits per tree. 10 cm pruning intensity advanced the average fruit weight.

4.2 Fruit Volume

In guava trees, Sahar and Hameed [52] reported that pruning at 20 cm gave highest fruit volume in both seasons. Regarding to date, pruning at May gave highest significant values in both seasons. The interaction between two studies factors, pruning at 20 cm with May and June pruning gave highest significant values in first season, while pruning at 20 cm with May pruning gave highest significant value in second season. These results in agreement with [53] who found that fruit volume was improved at 20 cm level of pruning in guava fruits.

4.3 Fruit Length and Breadth

An improvement in fruit size with pruning has been observed in many studies. Sahay and Singh [38] conducted an experiment on regulation of cropping in guava. Deblossoming treatments significantly increased fruit size during winter season as compared to control. Singh and Dhaliwal [47] conducted an investigation on effect of different pruning levels on fruit yield and quality of Guava cv. Sardar. The maximum fruit length of 6.8 cm was observed in tree subjected to 30 cm pruning level. However the fruits produced by the trees which received 30 cm pruning level could not exhibit any significant edge over the fruits produced by the trees which received 10 and 20 cm pruning levels. Similar trend was observed in winter season. Mohammed et al. [18] noticed that fruit size was maximum in 60 cm pruning treatment during rainy season and in 30 cm pruning treatment during winter season. Brar et al. [42] studied the effect of three pruning intensities (15, 30 and 45 cm from the shoot tips and the unpruned trees as a control) on yield and quality of Guava cv. Sardar. They concluded that the length and breadth of fruits obtained from pruned trees were significantly higher than the fruits from unpruned trees. Singh et al. [48] studied the effect of pruning on crop regulation of Guava cv. Allahabad Safeda. They found that differences were non significant except for fruit breadth in summer season. Bhanu Pratap et al. [54] found that the size of mango fruit improved with the severity of pruning treatment under high density planting. Singh et al. [27] conducted a field study to examine the effect of low heading back on pear plant on photosynthesis, yield and fruit quality. Fruit size enlarged linearly with the intensity of pruning.

4.4 Total Soluble Solids

Total soluble solids (TSS) of guava fruits increased with the increasing severity of pruning [15,16,55,11]. However, [56,57,58] reported non significant effect of different pruning levels on TSS in different guava cultivars. Chandra and Govind [59] found that severe pruning (75%) resulted in the higher value of TSS (10.9%) in

guava *cv*. L-49 in the first year but fruits from control trees recorded the higher TSS (10.4%) followed by 50 per cent pruning treatment (10%) in the following year. Trees receiving 30 cm pruning level produced fruits with the highest TSS content i.e. 10.19 per cent and 11.14 per cent in rainy and winter season, respectively over the other treatments [47]. The treatment of bending of shoots given by [60] showed the highest TSS (10.60 ^{0}B) content of fruits in *cv*. L-49 followed by 20 cm pruning (10.36 ^{0}B) and minimum (9.39 ^{0}B) in control. Singh et.al, [48] studied the effect of three pruning intensities *viz*. T_1 (heading back of the current season shoots to the levels of 2 basal leaves), T_2 (total pruning of the flowering/fruit bearing portion of current season shoot), T_3 (heading back of terminal branches of their half length) and T_4 (control no pruning trees) of guava *cv.* Allahabad Safeda. Maximum TSS (8.15%) in summer was recorded in T_3 treatment, which was followed by T_4 treatment (7.75%). In winter season maximum TSS (9.12%) was recorded in T_2 treatment followed by T_3 treatment (8.87%) while minimum (7.45%) in control trees. Kumar and Rattanpal [25] reported that maximum TSS (10.40% and 11.05%) was found in fruits produced by trees subjected to removal of half vegetative growth at 6x4 m spacing and it was significantly higher than all other pruning treatments and minimum (9.30% and 9.81%) in control trees at closer spacing (6x4 m) in rainy and winter season, respectively. Sahar and Hameed [52] studied the effect of pruning on yield and fruit quality of guava trees. Pruning at 10 cm gave highest significant value. Regarding to date, pruning at May and June recorded highest significant values. The interaction between two studies factors, pruning at 10 cm and 20 cm with May and June showed highest significant values in the first season. In the second season, concerning to pruning treatments, pruning at 10 cm recorded highest significant value. Regarding date, pruning at May showed highest significant TSS value. The interaction between two studied factors, all pruning treatments with May and pruning 10 cm with June had highest significant values

4.5 Acidity

Fruit acidity decreased with increasing severity of pruning in both the seasons [11,38]. According to [59] higher acidity (0.56%) in guava fruit *cv*. L-49 was observed in 75 per cent pruning level and lower (0.46%) in 25 per cent pruning level in the first year. However, in the following year, control fruits gave more acid content (0.56%) followed by 50 per cent pruning level (0.53%). Sahay and Singh [38] revealed that least acidity (0.24 % in rainy and 0.36% in winter season) was measured from the fruits subjected to 50 per cent of pruning during both the seasons, whereas, maximum acid (0.36 and 0.49%) content was recorded in fruits from control tree in both rainy and winter season crops. Dubey et al. [11] also obtained higher acid content (0.37% and 0.53% in rainy and winter season, respectively) in fruit of guava cv. Allahabad Safeda under control and lowest (0.33% and 0.50% in rainy and winter season, respectively) in 75 percent pruning level of May. Reynolds and Wardle [61] reported that minimal pruning resulted in lowest acidity in two or three seasons than other pruning treatments in grape. Singh and Dhaliwal [47] revealed that all the pruning intensities could not alter the acid content of fruits significantly during the rainy season, however, during winter season 10 cm pruning level eclipsed the 20 cm and 30 cm pruning levels by recording significantly higher value of acidity (0.35%) in Sardar guava. Whereas, [15,16,58] could not get any influence of different pruning levels on the acidity of different cultivars. Brar et al. [42] reported that fruits from the trees pruned at 15 cm level showed maximum TSS (11.1% and 11.5% in rainy and winter season, respectively). In Northern Province of South Africa, the lowest acidity of 0.31% in mango fruit cv. Tommy Atkins was registered by a treatment in which terminal buds were removed just before a vegetative or floral flush in mid June 2002 [12]. In guava, [52] observed that control gave the highest acidity in both seasons. Regarding to date, pruning at May gave highest significant value in both seasons. The interaction between two studies factors, control with May recorded highest significant values in both seasons. These results are in agreement with [53] in guava.

4.6 Ascorbic acid

No significant effect of pruning on the ascorbic acid content of fruits has been observed. Bajpai et al. [15] reported that severity of pruning had no effect on the ascorbic acid content of guava fruits. [16,62] too obtained similar results in guava and sweet lime, respectively. However, [63] observed an improvement in vitamin C content of guava cv. Fan Retief, when pruning was attempted from September to December and fruits were picked in June for two consecutive years. Similarly, [64] observed the highest ascorbic acid contents from trees of ber

cv. Umran, where half of the branches were pruned from the base and remaining half to 15 buds. Dhaliwal and Kaur [49] studied the effect of severity of pruning on the fruit quality of guava with pruning intensity (0, 10, 20 or 30 cm) and found that the highest mean ascorbic acid content was registered with 30 cm pruning level (202.3 mg/100 g of pulp). Similarly, [47] [25] reported higher ascorbic acid content in severely pruned trees over control in rainy and winter seasons. Ascorbic acid content in rejuvenated guava (headed back) increased with the advancement of ripening if fruits in comparison to un-rejuvenated guava as reported by [27]. Sahar and Hameed [52] studied the effect of pruning on yield and fruit quality of guava trees. Control gave highest significant value in both seasons. Regarding to date, pruning at May gave highest significant value in both seasons. The interaction between two studies factors, control with May recorded highest significant values in both seasons.

4.7 Total Sugars

Bajpai et.al, [15] observed maximum percentage of total sugars (10.8) in severely (100 cm) pruned guava trees and minimum (9.0%) in control trees. Singh and Chauhan [22] in peach reported that total, reducing and non reducing sugars increased significantly with the increasing severity of pruning. Dubey et.al, [11] found that maximum total sugars (7.09% and 10.40%) were recorded at 100 percent pruning intensity and minimum (6.14% and 9.19%) in control trees during rainy and winter season, respectively. Sahay and Singh [38] revealed that deblossoming of summer season flowers with pruning of current shoots and urea spray significantly increased the total sugars in guava. On the contrary, [29] found that total sugars were not affected significantly by different pruning treatments. Kumar and Rattanpal [25] observed that total sugars were found the maximum (7.9% and 9.4%) in pruning by removal of half vegetative growth and minimum (7.1% and 7.4%) in control trees, respectively in both the seasons. Singh et al. [27] found maximum percentage (11.3%) of total sugars from rejuvenated trees (headed back) as compared to control (10.62%). Sahar and Hameed [52] studied the effect of pruning on yield and fruit quality of guava trees. Pruning at 10 cm gave highest significant value in both seasons. Regarding date, pruning at May and June gave highest significant values in both seasons. The interaction between two studies factors, pruning at 10 cm with May and June pruning gave highest significant values in both seasons.

4.8 Pectin Content

Dhingra et al. [65] showed the significantly higher percentage of crude pectin and jelly units in pruned trees. Sahay and Singh [38] revealed that deblossoming of summer season flowers with pruning of current shoots and urea spray significantly increased the pectin content in guava. In Pakistani and Ganib cultivars of guava, pectin content was found to reach its maximum when the trees were pruned up to 25% as reported by [66]. Sahar and Hameed [52] studied the effect of pruning on yield and fruit quality of guava trees. Pruning at 10 cm gave highest significant pectin content in both seasons. Regarding to date, pruning at May and June gave highest significant values in both seasons. The interaction between two studies factors, pruning at 10 cm with May and June pruning gave highest significant values in both seasons.

5. CONCLUSION

On the basis of above findings, it can be concluded that training and pruning in guava trees can enhance the productivity under high planting density. Guava bears on current season's growth and flowers appear in axils of leaves, therefore, it responds well to pruning. Pruning will not only restore the balance between shoot and root system but will also maintain growth and vigour of shoots by allowing fewer growing points to growing vigorously.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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