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Response of guava var. Arka Amulya to branch bending during winter and summer in the Eastern tropical region of India

D. Samant* and K. Kishore

ICAR-IIHR-Central Horticultural Experiment Station, Bhubaneswar-751 019, India

***Corresponding Author Email :** horti.deepa@gmail.com

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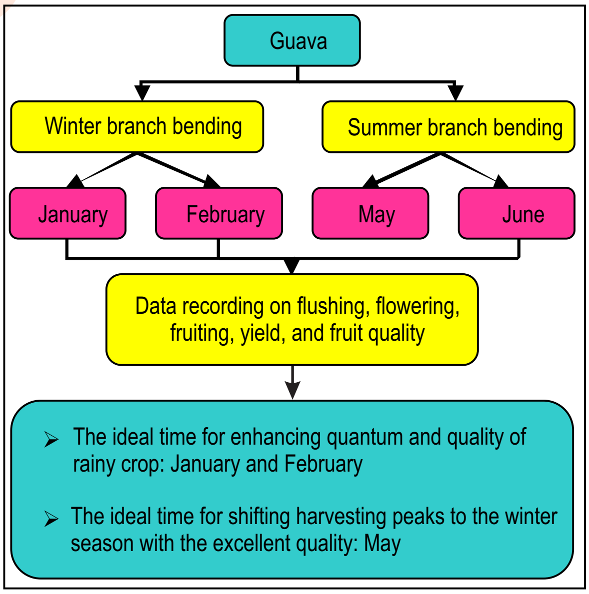
Abstract

Aim: The study aimed to evaluate the comparative response of guava var. Arka Amulya to branch bending practice during winter and summer for controlling shoot vigour and improving flushing, yield, and quality of harvest under hot and humid climate of Odisha.

Methodology: The experiment was laid out in a Randomized Block Design with five treatments consisting of branch bending during first week of January, February, May, June, and without branch bending as control. Each treatment was replicated four times and each replication unit had four plants. Observations were recorded on flushing, flowering, yield, and fruit quality parameters.

Results: Branch bending technique was found effective for controlling the shoot vigour and enhancing flushing, flowering, and yield in guava, when practised during January, February, and May, however, effects were more pronounced when branch orientation was manipulated during winter months. January branch bending produced the shortest vegetative shoots (50.48 cm) and recorded the maximum value for flush count (28.91 shoots m^{-1} branch), flowering (57.91%), and fruit yield (38.46 kg per tree). Branch manipulation during winter resulted in higher yield gains (70.87-81.59%) over control (21.18 kg per tree) as compared to summer months (11.99-42.21%). All the treatments of branch bending caused a significant improvement in various fruit quality attributes, however, May and June treatments excelled in the performance. June bending produced the best quality fruit (TSS: 11.35ºB, Total sugar: 7.85%, Vitamin C: 197.39 mg 100 g^{-1} pulp, Total phenolic content: 117.29 mg GAE 100 g^{-1} FW, and total flavonoid: 52.74 mg QE 100 g^{-1} f. wt.), followed by May bending.



Interpretation: In guava, canopy architecture manipulation through branch bending appears to hold immense potential for enhancing the quantum and quality of produce, if practised at suitable time. Practising this technique after May month would not give significant yield gain over the control plant.

Key words: Branch bending, Flushing, Fruit quality, Guava, Shoot- vigour

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Introduction

Guava (*Psidium guajava* L.), belonging to family Myrtaceae is the fifth most widely cultivated fruit crop in India after mango, citrus, banana, and apple. It is well recognized for its hardy nature, wider edapho-climatic adaptability, early bearing habit, high production potential, and exceptional nutritional and health-promoting properties (Samant and Kishore, 2019; Singh *et al.,* 2015). The fruit is consumed fresh as well as in processed form, such as jam, jelly, juice, nectar, cheese, squash, leather, and puree (Kanwal *et al.,* 2016; Choudhary *et al.,* 2008). It is cultivated throughout the tropical and sub-tropical parts of the country on 2.65 lakh ha area with an annual production of 4.05 million tonnes (NHB, 2018). Uttar Pradesh, Madhya Pradesh, Bihar, Chhattisgarh, West Bengal, Odisha, Gujarat, and Haryana are the major guava growing states in the country. In Odisha, it is cultivated on 14.27 thousand ha area with 1.05 lakh tonnes of annual production (NHB, 2018). Despite having the sixth-largest area under guava cultivation in the country, the state lags in production by securing 13th position.

The productivity of guava obtained in the state (7.36 t ha^{-1}) is way half to the national average productivity (15.30 t ha^{-1}). Vigorous shoot growth favoured by hot and humid climate of Odisha could be one of the possible constraints in realizing high yield potential of guava, as it appears to interfere with the production of lateral shoots. Moreover, under the influence of vigorous growth, the buds present in leaf axil give rise to vegetative growth instead of flowers. Thus, flowering is compromised at the cost of luxuriant shoot growth. Guava plant bears flowers on new lateral shoots emerging from mature wood or past season's growth (Mehta *et al.,* 2012; Kumar and Rattanpal, 2010). Thus, the production of new laterals is the key factor deciding the crop load in guava. The emergence of more number of laterals on a branch ensures profuse flowering and heavy fruiting. Lateral shoot production in guava could be enhanced by branch architecture manipulation practices such as branch bending which suppresses apical dominance and activates dormant lateral buds by interrupting the polar transport of auxin (Wilson, 2000; Bangerth, 1993).

Branch bending has been reported to reduce shoot growth and enhance flushing, flowering, and fruiting in various fruit trees, *viz.,* mandarin (Budiarto *et al.,* 2018), guava (Mitra, *et al.,* 2008; Sarkar *et al.,* 2005), apple (Han *et al.,* 2007), and cherry (Lauri *et al.,* 1998). In guava, branch bending studies have been conducted primarily for crop regulation, *i.e.,* for increasing the share of off-season crops either in winter or spring-summer season (Nandi *et al.,* 2017; Mamun *et al.,* 2012). Information on the comparative evaluation of branch bending for main season (rainy) and off-season crops (winter and spring-summer) is not available. According to Sheriff (2012) and Lauri and Lespinasse (2001), the response of a plant to bending varies with the genotype and time of bending. Thus, it is of utmost importance to study the response of guava to the time of branch bending. In Odisha, guava flowers twice a year during spring (March-April) and the rainy season (July-August). Spring flowering (*ambe bahar*) is intense and produces heavy crop (80-85%) during the rainy season, *i.e.,* August-October, whereas, rainy season flowering (*mrig bahar*) is sparse and gives light crop (15-20%) during winter, *i.e.,* December-January (Samant *et al.,* 2016). Considering the flowering season of guava in the state and keeping in view all the above background information and research gaps, the present investigation was undertaken, wherein the comparative response of guava to winter (January and February) and summer (May and June) branch bending was evaluated to find out suitable time of branch bending for enhancing guava productivity in the region.

Materials and Methods

The current study was carried out in the Eastern coastal region of India at the research farm of ICAR-IIHR-Central Horticultural Experiment Station, Bhubaneswar, Odisha during 2015-2019. The red lateritic soil of experimental site was sandy loam (78.45% sand, 13.42% silt, and 8.13% clay), strongly acidic (pH 4.61), low in organic carbon (0.21%), available nitrogen (185.13 kg ha^{-1}), phosphorus (10.50 kg ha^{-1}), and potassium (118.26 kg ha^{-1}). Fifteen-year-old Arka Amulya guava plants of uniform vigour and size, spaced 5 m × 5 m, and maintained under uniform cultural practices were selected for the study. The experiment was laid out in a Randomized Block Design with five treatments consisting of branch bending during first week of January (T1), February (T2), May (T3), and June (T4), and without branch bending as control (T5). Each treatment was replicated four times and each replication unit had four plants. Branch bending was done as per the method described by Samant *et al.* (2016).

Observations were recorded on flushing parameters, *viz.,* flushing intensity (no. of shoots m^{-1} branch), length of flowering and vegetative shoots (cm), and leaf chlorophyll content (atLEAF unit); characteristics of flowering and fruiting, *viz.,* flower development period (days), flowering duration (days), flowering intensity (%), fruit set (%), fruit drop (%), fruit maturity season, yield (kg per tree), average fruit weight (g per fruit), and the number of fruits per plant; and on fruit quality parameters, *viz.,* TSS (ºB), acidity (% equivalent of citric acid), TSS/acid ratio, sugar content (%), vitamin C (mg 100 g^{-1} pulp), total phenolic content (mg gallic acid equivalent 100 g^{-1} f. wt.), total flavonoid content (mg quercetin equivalent 100 g^{-1} f. wt.), scavenging activity (%), and ferric reducing antioxidant power (mM $Fe_{(II)}$ 100 g^{-1} f. wt.).

For recording observations on various parameters of flushing, four branches (one in each direction of the plant canopy) were selected randomly and tagged. On these branches, the total number of shoots and flowering shoots were counted after two months of flushing. Flushing intensity was worked out by dividing the total number of shoots by branch length, whereas, the flowering intensity was determined by dividing the number of flowering shoots by total number of shoots and expressed in percentage. To ascertain the period of flower development, 40 shoots (10 shoots in each direction of the plant canopy) were tagged and the period required from the appearance of bud sprout, *i.e.,* small outgrowth in leaf axil to its transformation into flower was recorded. To record observations on shoot growth, fruit set, and fruit drop, 40 vegetative and 40 flowering shoots were tagged in each plant (10 vegetative and 10 flowering shoots in each direction of the plant canopy). Shoot length was measured after 180 days of their emergence.

Fruit set was computed by counting the number of fruits on tagged flowering shoots at 21 days after anthesis and expressed in percentage. Fruit drop was worked out on the basis of number of set fruits and number of fruits reached to harvesting stage and expressed in percentage. Duration between the initial and final availability of mature fruit was considered as the period of fruit maturity or harvest. For the estimation of leaf chlorophyll content, 40 vegetative shoots of five-month-old maturity were selected in each tree (10 shoots in each direction of the plant canopy). Thereafter, chlorophyll content of 4^{th} leaf pair (from the base of the shoot) was measured with the help of a hand-held chlorophyll meter (atLEAF) on 5 points avoiding mid-rib area. Direct sunlight was avoided while taking observations. Chlorophyll content was expressed in chlorophyll index, *i.e.,* atLEAF unit. Fruits were harvested at full maturity, counted and weighed with physical balance, and yield was expressed in kg $tree^{-1}$. The average fruit weight was computed by dividing the yield by the number of fruits obtained.

Ten mature fruits from each replication unit were taken randomly for recording observations on various quality attributes. Total soluble solids (TSS) were determined using a hand-held digital refractometer (Hanna make). Acidity, sugar (reducing, non-reducing, and total sugar), and vitamin C were estimated following the protocol of AOAC (2000). Total phenolic content (TPC) and scavenging activity (SCA) were estimated with Folin-Ciocaltu (FC) reagent and 2-diphenyl-1-picrylhydrazyl (DPPH) free radical assay, respectively (Ikram *et al.,* 2009). Total flavonoid content (TFC) was determined by aluminium chloride colorimetric method (Chang *et al.,* 2002), whereas, ferric reducing antioxidant power (FRAP) assay was performed as per the method described by Benzie and Strain (1999). The data generated on various parameters during four consecutive years (2015-16, 2016-17, 2017-18, and 2018-19) were pooled and statistically analyzed with OPSTAT (Sheoran, 1998) for the interpretation of results and drawing conclusions.

Results and Discussion

A perusal of flushing data presented in Fig. 1 showed the significant improvement in flushing and containment of shoot growth by branch bending when practised during January, February, and March, however, effects were more pronounced when branch orientation was manipulated during winter months (T1 and T2). Performance of June branch bending (T4) remained at par with the control. Bending of branches during January produced the highest flush count (28.91 shoots m^{-1} branch) and shortest shoots (flowering: 38.75 cm, vegetative: 50.48 cm), whereas, the lowest flushing intensity (16.08 shoots m^{-1} branch) and longest shoots (flowering: 56.21 cm, vegetative: 68.35 cm) were noted in control plants. Intensive production of lateral shoots under branch bending treatments could be attributed to disruption of auxin-mediated apical dominance (Wilson, 2000). Auxin, which moves downwards in plants from site of production (growing shoot tips) inhibits sprouting of lateral buds by inhibiting cytokinin biosynthesis and promoting strigolactone biosynthesis (Muller and Leyser, 2011; Beveridge *et al.,* 2009; Shimizu-Sato and Mori, 2001).

The basipetal transport of auxin in plant is suggested to be interrupted due to bending of branches (Bangerth, 1993), which in turn could have altered the levels of cytokinin and strigolactone in the dormant lateral buds causing their activation. As far as containment of shoot growth by branch bending is concerned (T1, T2, and T3), it might be due to less availability of metabolites, nutrients, and water to a large number of shoots. The beneficial effects of branch bending on flush count and shoot vigour control observed in the present study are in line with the findings of Aly *et al.* (2012), Mamun *et al.* (2012), and Lauri *et al.* (1998). The flowering response of guava to physical branch manipulation is presented in Table 1. The perusal of data revealed that the flower development period and flowering duration were significantly influenced by the branch bending treatments, irrespective of the season. In bent trees, floral bud took a shorter time (28.78-30.21 days) from its sprouting stage to anthesis than in control trees (33.94 days). Likewise, flowering duration too got reduced by the bending treatments, wherein it ranged from 44.65 to 50.17 days as against a period of 81.76 days noted in control.

Branch bending is suggested to enhance the sink strength and source capacity by facilitating more light penetration inside the plant canopy and maintaining higher levels of endogenous cytokinin, which in turn might have accelerated the developmental process of floral bud and reduced the flowering duration (Azizu *et al.,* 2016; Han *et al.,* 2008; Ito *et al.,* 1999). In the present study, leaf chlorophyll which is considered an important indicator of photosynthetic efficiency was found to be significantly high in guava plants which received branch manipulation treatments (Fig. 2). This supports the role of bending in enhancing source capacity. Effect of branch bending on shortening the flowering period over control could further be explained by the fact that under climatic conditions of Bhubaneswar guava starts shedding its leaves in the last week of January and continues over a long period till mid-March. In contrast, plants were manually defoliated at once while practising branch bending.

Concerning flowering intensity, the response of guava to branch bending appeared to vary significantly with the time of operation (Table 1). January was the best time for bending as it

Table 1: Effect of time of branch bending on characteristics of flowering and fruiting in guava var. Arka Amulya

Treatment	Flower development period (days)	Flowering duration (days)	Flowering intensity (%)	Fruit set (%)	Fruit drop (%)	Fruit maturity period	Yield (kg per tree)	Fruit weight (g per fruit)	No. of fruits per plant
T1	28.78	50.17	57.91	61.71	47.57	July (2^{nd} wk) - August	38.46	170.67	226.24
T2	29.15	48.32	54.15	62.14	48.16	August (2^{nd} wk) - September	36.19	173.12	209.65
T3	29.87	45.89	45.14	63.10	44.26	November (3^{rd} wk) - December	30.12	184.41	164.21
T4	30.21	44.65	32.86	64.28	43.84	December (3^{rd} wk) - January	23.72	195.85	121.25
T5	33.94	81.76	28.74	61.25	47.72	August- October (3^{rd} wk)	21.18	197.31	107.48
SE(m)±	0.68	7.60	1.81	1.78	1.98	-	1.87	3.14	13.29
CD(P=0.05)	2.17	22.95	8.51	ns	ns	-	5.71	9.77	41.39

T1: January branch bending; T2: February branch bending; T3: May branch bending; T4: June branch bending; T5: Control; wk: week; ns: non-significant

Table 2: Effect of time of branch bending on fruit quality in guava var. Arka Amulya

Treatment	Chemical quality attributes						Bioactive constituents		Antioxidant capacity		
	TSS (ºB)	Acidity (%)	TSS/acid ratio	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Vitamin C (mg $100g^{-1}$ pulp)	TPC (mg GAE $100g^{-1}$ f. wt.)	TFC (mg QE $100g^{-1}$ f. wt.)	FRAP (mM $Fe_{(II)}$ $100g^{-1}$ f. wt.)	SCA (%)
T1	9.80	0.61	16.07	6.58	4.21	2.37	181.96	78.65	39.86	18.96	59.47
T2	10.14	0.63	16.10	6.61	4.08	2.53	182.42	80.71	41.75	19.58	60.18
T3	11.16	0.58	19.24	7.64	5.21	2.43	194.54	115.54	50.17	24.67	65.91
T4	11.35	0.57	19.91	7.85	5.29	2.56	197.39	117.29	52.74	25.12	66.85
T5	9.06	0.67	13.52	5.47	3.07	2.40	170.15	71.18	33.45	15.86	55.27
SE(m)±	0.26	0.06	0.75	0.31	0.27	0.12	3.45	2.01	1.35	0.69	1.03
CD (P=0.05)	0.67	ns	2.27	0.94	0.86	ns	10.48	6.12	4.16	2.13	3.14

T1: January branch bending, T2: February branch bending, T3: May branch bending, T4: June branch bending, T5: Control, TSS: Total soluble solids, TPC: Total phenolic content, TFC: Total flavonoid content, FRAP: Ferric reducing antioxidant power, SCA: Scavenging activity, GAE: Gallic acid equivalent, QE: Quercetin equivalent, FW: Fresh weight, ns: non-significant

recorded the maximum flowering (57.91%). Branch bending beyond May was ineffective to register a significant gain in flowering over control (28.74%). Induction of profuse flowering due to bending could be attributed to its influence on enhancing C/N ratio, source capacity, and sink strength, and on maintaining lower levels of gibberellins and higher levels of flowering related plant hormones, *viz.,* cytokinin, abscisic acid, and ethylene (Budiarto *et al.,* 2018; Samant *et al.,* 2016; Wang *et al.,* 2010, Ito *et al.,* 1999; Sanyal and Bangerth, 1998).

In the present investigation, the majority of branch bending treatments (T1, T2, and T3) exhibited significant influence on average fruit weight and quantum of fruit harvest in terms of fruit number and yield over control, however, none of the treatment registered significant changes for fruit set and fruit drop (Table 1). Fruit number and yield followed a decreasing trend with the advancement of time of branch bending from January to June, whereas, fruit weight followed an increasing trend. Of four canopy manipulation treatments, the January branch bending (T1) produced the highest fruit yield (38.46 kg per tree) with the maximum number of fruits (226.24 fruits per tree) whereas the June bending (T4) recorded the lowest value for fruit number and yield (121.25 fruits per tree and 23.72 kg per tree, respectively) and remained at par with the control (107.34 fruits per tree and 21.18 kg per tree, respectively). With respect to fruit weight, all the treatments of branch bending, except T4 resulted in a significant reduction in fruit weight. The highest fruit weight was recorded in control plants (197.31 g per fruit), whereas, the lowest was in January branch bending (170.67 g per fruit). Heavy crop load in bent guava plants could be the reason for significant reduction in fruit weight. Under heavy crop load conditions, it is obvious that there would be more competition for photo-assimilates among developing fruits resulting in reduced fruit size and weight. The negative correlation observed in the present study, between fruit weight and number of fruits is in support with the findings of Patil *et al.* (2017). Significant improvement in fruit yield by branch bending treatments (T1, T2, and T3) could be the result of intense flushing and profuse flowering observed under these treatments (Fig. 1 and Table 1).

Various attributes of fruit quality, *viz.,* chemical parameters, bioactive constituents, and antioxidant capacity estimated under the present investigation are shown in Table 2. In general, branch bending during winter and summer season,

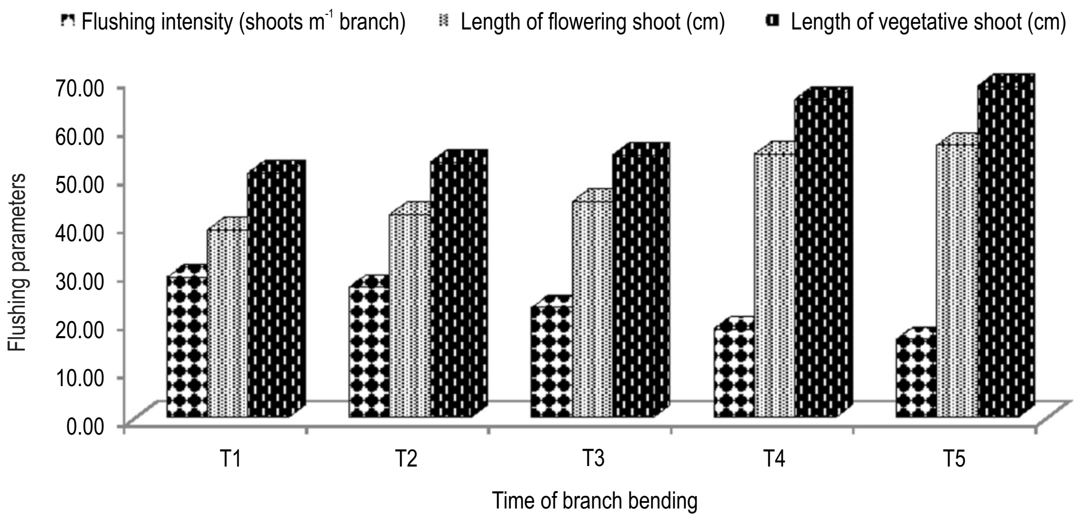

Fig. 1: Effect of time of branch bending on flushing in guava var. Arka Amulya. T1: January branch bending; T2: February branch bending; T3: May branch bending; T4: June branch bending and T5: Control

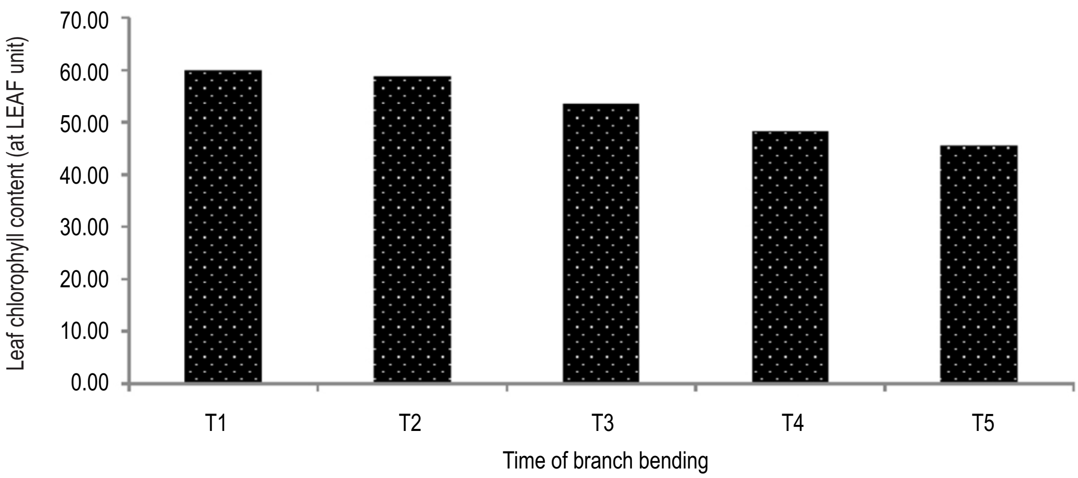

Fig. 2: Effect of time of branch bending on leaf chlorophyll content in guava var. Arka Amulya. T1: January branch bending; T2: February branch bending; T3: May branch bending; T4: June branch bending and T5: Control

both caused a significant improvement in most of fruit quality parameters, except acidity and non-reducing sugar. Improvement in TSS, TSS/acid ratio, total sugar, reducing sugar, and vitamin C could be the outcome of better light penetration and air circulation inside the open canopy of bent plants as compared to dense canopy of control plants, resulting in more synthesis, transport, and accumulation of photo-assimilates. With respect to enhancement in bioactive constituents (TPC and TFC), stimulation of plant's defence system in response to shock experienced during bending operation on account of severe defoliation and forceful reorientation of branches towards ground could be the probable reason. To overcome the shock effect of bending, the plant could have produced more secondary metabolites, *viz.,* phenols.

The perusal of data further showed the superiority of summer branch bending treatments (T3 and T4) over winter season treatments (T1 and T2). Of four treatments, June branch bending (T4) had the best quality fruits in terms of TSS (11.35ºB), TSS/acid ratio (19.91), total sugar (7.85%), reducing sugar (5.29%), Vitamin C (197.39 mg 100 g^{-1} pulp), TPC (117.29 mg GAE 100 g^{-1} f.wt.), TFC (52.74 mg QE 100 g^{-1} f.wt.), FRAP (25.12 mM $Fe_{(II)}$ 100 g^{-1} f.wt.), and SCA (66.85 %), followed by T3 (May branch bending). Significant gain in fruit quality attained by summer branch bending over winter may be the effect of season during which guava crop gets ready for harvesting. Fruit load of winter branch bending treatments (T1 and T2) reached harvesting stage during rainy season from 2nd week of July to September, whereas, in summer branch bending, produce attained maturity during winter from 3rd week of November to January (Table 1). Our results are in agreement with the findings of Nandi *et al.* (2017) who obtained quality produce in guava due to May and June branch bending. The results of the present study revealed the potential of branch bending for enhancing the fruit yield and quality in guava. Yield gains over control were significantly at higher side when bending was performed during winter (70.87-81.59%) than in summer (11.99-42.21%). If the quality of harvest is considered, summer branch bending outperformed the winter branch manipulation. However, the time of branch bending is crucial for reaping the benefits of this technique in guava. Practising this technique beyond May would not result in noticeable yield gain over major fruiting season (rainy crop) of control plant (21.18 kg per tree). Branch bending studies conducted in different parts of the world on various crops including guava have also reported superiority of some season or months over others (Nandi *et al.,* 2017; Sherif, 2012; Lauri and Lespinasse, 2001).

It can be concluded that under hot and humid climate of Odisha, branch bending can be practised in guava during winter (January-February) to enhance the quantum and quality of rainy season crop whereas May is the best summer month to perform branch bending for shifting harvesting peaks to winter with the maximum gain in fruit quality.

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Add-on Information

Authors' contribution: D. Samant: Writing- original draft, writing-review and editing, Investigation, Methodology, Visualization, Formal analysis; **K. Kishore:** Methodology, Estimation of chemical attributes of fruit quality.

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