Journal of
Food Chemistry & Nanotechnology

https://doi.org/10.17756/jfcn.2023-s1-030

Research Article

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Response of Off-season Growth Manipulation Through Varying Concentrations of Plant Hormone and Branch Bending on Qualitative Traits of Guava

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Received: September 14, 2023
Accepted: October 27, 2023
Published: October 31, 2023

Citation: Jabroot K, Saxena D, Chaudhuri M, Rodge R. Sargam K. 2023. Response of Off-season Growth Manipulation Through Varying Concentrations of Plant Hormone and Branch Bending on Qualitative Traits of Guava. *J Food Chem Nanotechnol* 9(S1): S237-S242.

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Abstract

Guava (*Psidium guajava* L.) from the Myrtaceae family whose pericarp is a rich source of various antioxidants has also emerged as an excellent processed product. Three flowering seasons mirg, ambe, and hasta are observed by the guava tree where hasta yields good-quality fruits but is not satisfactory enough to feed the population. Crop regulation techniques such as branch bending and plant growth regulators (PGR) like gibberellins (GA_3), 1-naphthaleneacetic acid (NAA), and ethrel positively influence fruit biochemical attributes. Hence a trial was set up at Lovely Professional University, for the selection of desirable months from the off-season months viz., September, October, and November with varying concentrations of plant hormones specifically GA_3, NAA, and ethrel with branch bending to amplify the quantitative traits in guava cv. Allahabad Safeda. Different biochemical characteristics were examined, including total soluble solids (TSS), total sugar, reducing and non-reducing sugars, ascorbic acid, totable acidity, and pectin content. Amongst the months under study, October gave favorable outcomes for all parameters with the highest mean values TSS (11.41 °Brix), total sugar (6.79%), reducing sugar (4.26%), non-reducing sugar (2.52%), ascorbic acid (149.75 mg/100 g pulp), titratable acidity (0.33%) and pectin (1.17%). Whereas combinations of GA_3@200 ppm plus branch bending in October have maximized results in TSS (12.18 °Brix), total sugar (8.13%), reducing sugar (5.15%), non-reducing sugar (2.97%) while ascorbic acid (178.42%) and titrable acidity (0.25%) recorded its optimum performance with GA_3@150 ppm plus October branch bending while NAA@200 ppm plus October branch bending had the best influence on pectin content (1.73%). GA_3 influenced most biochemical traits except in pectin. Thus, these findings will benefit farmers in enhancing quantitative parameters by selecting an appropriate month and crop regulation measures from the off-season.

Keywords

Branch bending, Ethrel, Gibberellin, Naphthaleneacetic acid, Plant growth hormone

Introduction

One of the most well-known fruits growing in India's tropical and subtropical regions is the guava (*Psidium* sp.), a member of the Myrtaceae family. *P. guajava* L. is the most cultivated guava species [1]. According to historical records, guava cultivation began in the Indian subcontinent in the early 17th century [2]. Guava is becoming increasingly well-liked in our country because of its excellent nutritional and medicinal value, frequent bearing habits, and adaptation to various agroclimatic conditions. In addition to having a healthy quantity of iron, calcium, and phosphorus, guava fruit pulp contains 260 mg of vitamin C per 100 g. It also contains 2.45% reducing sugar, 2.23% non-reducing sugar, 9.73% TSS, and 0.48% ash. The raw and processed versions of the fruit are eaten, including

jam, jelly, juice, nectar, cheese, squash, leather, and puree [3, 4]. Guava ripens quickly and can be kept for two to three days at room temperature despite being highly perishable [5].

With an annual production of 4304 MT, it is grown on 287 Ha of land throughout India's tropical and subtropical regions [6]. Countries that are major producers of guava include India, China, Thailand, Pakistan, Mexico, Indonesia, Brazil, Bangladesh, the Philippines, and Nigeria. In past centuries India, Pakistan, and Brazil have been the primary sources of commercially cultivated guava varieties on a global scale [7].

For quality enhancement, plant hormones play a pivotal role in guava production by directly or indirectly regulating several plant activities, such as germination, roots, and the biochemical characteristics of guava. Growth regulators like GA_3 and NAA have significant impacts on multiple aspects of plant growth. They influence processes like flower and fruit formation, cell growth, the dominance of the apical bud, gravitropism, and phototropism. GA_3 encourages flower and fruit development, while NAA promotes cell elongation and division, aiding overall growth. It has been discovered that auxins and GA_3 both speed up the transfer of metabolites from other areas of the plant to grow fruits. On the other hand, the use of ethephon as a pre-harvest spray enhances the color of the fruit's surface improves overall fruit quality and accelerates the fruit's ripening process [8]. Furthermore, utilizing the growth regulators spray also amplifies fruit weight, TSS, carotene, reducing sugars, total sugars, and vitamin C, while diminishing tannin levels and fruit acidity [9]. This method is adopted to achieve elevated fruit production and enhanced fruit excellence [10, 11]. These plant hormones weren't precisely become very popular, though.

In Southern India and the Deccan plateau, guava undergoes three flowering cycles annually, while in Northern India, it blooms twice a year: first in April-May for the rainy season harvest and then in August-September for the winter season crop. Temperature and humidity notably impact guava quality, leading to superior winter fruits compared to the rainy season. In subtropical areas viz., Punjab, Haryana, Uttar Pradesh, north Indian district of West Bengal, and Bihar inadequate heat during winter limits commercial production, and it takes around 200 days from flowering to harvest. Low temperatures in December-January prevent proper on-tree ripening, resulting in hard fruits [12]. Owing to this, potential quality yield is not obtained during the desired period. Therefore, to obtain higher fruit yield during a particular period, it needs a resting period with artificial means so that the natural flowering tendency of the trees is altered which is termed crop regulation altogether.

Crop regulations practice encompasses various methods, in which branch bending has been shown to improve flushing, blooming, and fruiting in various fruit trees while decreasing shoot growth. To increase the share of off-season crops in the winter or spring-summer season, branch-bending experiments in guava have been undertaken mostly for crop regulation [13, 14]. Bending of branches may disrupt the basipetal transport of auxin in plants, which may change the amounts of cytokinin and strigolactone in the dormant lateral buds and reactivate them [15] while physiologically when a branch is bent, it can lead to increased tension in the branch wood and a reduction in the formation of phloem. As a result, the movement of photosynthetic products from the bent branch to other parts of the plant slows down. This can cause an elevated ratio of carbohydrate to nitrogen (C:N ratio), potentially promoting the plant to prioritize flowering and fruit production [16].

Inevitably, guava fruits only bear periodically during the spring and summer, with little to no fruiting during the rainy while in winter seasons farmers fetch mediocre prices because guava fruits are available in ample amounts which ends the competition. As in North India prominent flowering months are April to May and August to September [17] although the work on manipulation of the flowering period (August to September) is less documented.

Hence an experiment was carried out to influence the flowering of guava trees during the period of September to November, utilizing branch-bending techniques in combination with the application of plant hormones. This research paper aims to provide a concise overview of how these approaches impacted the biochemical aspects of guava cultivation. The outcomes of this study could offer valuable insights into advancing guava production and improving its overall quality through crop regulation for substantial off-season production.

Materials and Methods

Experimental detail

The research trial was carried out during 2022 - 2023 on six-year-old guava cultivar Allahabad Safeda planted at a distance of 6 x 5 m in the orchard at a horticulture farm, School of Agriculture Lovely Professional University, Phagwara, Punjab. The experimental design was laid out in randomized block design consisting of three replications with each replication comprising of one plant. A total of sixty-three plants were selected and tagged for study in which twenty-one plants were undertaken for each month. PAU prescribed cultural practices and fertilizer doses were incorporated into the orchard.

Branch bending was practically performed in the morning hours 8 to 10 AM preferably. Starting with manual defoliation of leaves from straight upright stems, by keeping 10 - 12 inches twig intact. Later selected branches were exposed to bending after the emergence of tender shootlets with a height of approx. 1 cm, branches were untied, followed by PGR application. The fourth week of three different months namely, M_1 - September, M_2 - October, and M_3 - November was chosen for the bending operation along with three PGRs with two varied concentrations and one control specifically C_1 - NAA@100 ppm, C_2 - NAA@200 ppm, C_3 - Ethrel@200 ppm, C_4 - Ethrel@400 ppm, C_5 - GA_3@150 ppm, C_6 - GA_3@200 ppm, and C_0 - Control. Total twenty-one treatments were formed by the combination of (M) branch bending months and PGR (C) viz., T_1 (M_1C_1),T_2 (M_1C_2), T_3 (M_1C_3), T_4 (M_1C_4), T_5 (M_1C_5), T_6 (M_1C_6), T_7 (M_1C_0), T_8 (M_2C_1), T_9 (M_2C_2), T_{10} (M_2C_3), T_{11} (M_2C_4), T_{12} (M_2C_5), T_{13} (M_2C_6), T_{14} (M_2C_0), T_{15} (M_3C_1), T_{16} (M_3C_2), T_{17} (M_3C_3), T_{18} (M_3C_4), T_{19} (M_3C_5), T_{20} (M_3C_6), and T_{21} (M_3C_0).

Evaluation of biochemical attributes

Ten mature fruits were randomly selected from each experimental unit to record observations. TSS was measured using a hand refractometer while for total sugar [18] method was employed where 5 ml of HCl was used with phenolphthalein and 0.1 N NaOH, the mixture is titrated, and the total sugar content is expressed as a percentage. Lane and Eynon method were used for continuous reducing sugar measurement. Non reducing sugar was measured by subtracting reducing sugar from total sugar. Titrable acidity was measured using [19] guideline by titrating the solution against NaOH until appearance of pink colour while ascorbic acid was determined by Ranganna [18] procedure with HPO_3 solution. Pectin content was calibrated using [20] estimation method. Statistical assessment was conducted utilizing the OPSTAT software through a two-factorial analysis of variance (ANOVA) with the significance level of 0.05.

Results and Discussion

TSS, total sugar, reducing sugar and non-reducing sugar

Data related to TSS, total sugar, reducing sugar, and non-reducing sugar is shown in table 1 depicts significant variation among the combinations formed in treatment. TSS, total sugar, reducing and non-reducing sugar values are positively correlated with the branch bending operation carried out in the month of October (M_2) with mean values 12.18 °Brix, 6.79%, 4.26%, and 2.52% respectively while in comparison September (M_3) month bending exerted negligible effect. The application of plant hormones has certainly boosted the range of sugar-associating parameters although GA_3 spray at 200 ppm (C_6) was revealed as the greatest performing PGR with mean values of 11.85 °Brix, 7.8%, 5,00%, and 2.85% respectively whereas, ethrel (C_4) submitted the lowest possible value in comparison to all growth hormone spray. Moreover, TSS exhibited a potential rise with the incorporation of branch bending in October month, and a spray of GA_3 @200 ppm (T_{12}) with 12.18 °Brix and control in the month of September (T_7) gave the lowest reading amongst all the interactions of treatments at 7.73 °Brix. A similar trend was followed by the remaining traits, total sugar (5.33%), reducing sugar (3.39%), and non-reducing sugar (1.94%). Figure 1, figure 2, figure 3 and figure 4 will provide more understanding. The results are in conformity with the findings of Sharma and Tiwari [12] and Kumar et al. [21]. A possible reason for the increase in sugar percentage through PGR could be the redirecting of a greater portion of substances toward fruit development and potentially facilitating the transformation of complex polysaccharides into simpler sugars and stimulating the functioning of several enzymes through physiological processes [22]. Delayed ripening of the fruit allowed more time

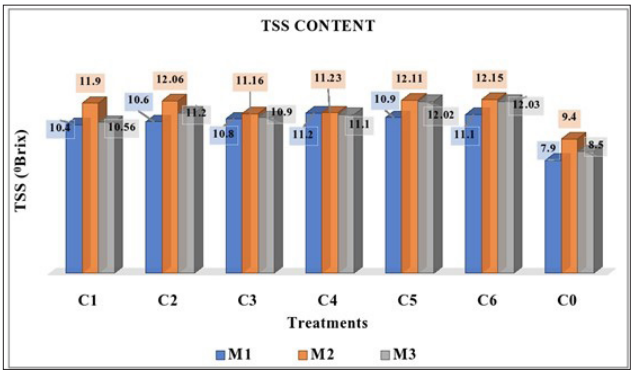

Figure 1: Graphical representation of branch bending and PGR application on TSS content.

Table 1: Effect of branch bending and PGR application on TSS, total sugar, reducing sugar, and non-reducing sugar content.

Parameter	M	C_1	C_2	C_3	C_4	C_5	C_6	C_0	Mean (C)
TSS (°Brix)	M_1	10.4	10.6	10.63	11.13	11.2	11.33	7.73	10.4
	M_2	11.66	12	11.16	11.23	12.12	12.18	9.5	11.41
	M_3	10.56	11.2	10.86	11.03	12.02	12.06	8.26	10.86
	Mean (C)	10.87	11.26	10.88	11.13	11.78	11.85	8.5	
CD at 5%		C = 0.203		M = 0.133			C × M = 0.352		
Total sugar (%)	M_1	6.81	6.81	6.10	5.90	7.19	7.54	5.33	6.52
	M_2	7.14	7.19	6.08	6.09	7.37	8.13	5.53	6.79
	M_3	6.84	6.68	6.4	5.79	7.28	7.90	5.42	6.61
	Mean (C)	6.93	6.89	6.19	5.93	7.28	7.85	5.42	
CD at 5%		C = 0.111		M = 0.072			C × M = 0.192		
Reducing sugar (%)	M_1	4.29	4.26	3.70	3.75	4.47	4.8	3.39	4.09
	M_2	4.34	4.42	3.97	3.85	4.54	5.15	3.55	4.26
	M_3	4.28	4.09	3.76	3.62	4.52	5.06	3.46	4.11
	Mean (C)	4.30	4.26	3.81	3.74	4.51	5.00	3.46	
CD at 5%		C = 0.097		M = 0.063			C × M = 0.163		
Non-reducing sugar (%)	M_1	2.51	2.55	2.4	2.15	2.72	2.74	1.94	2.43
	M_2	2.75	2.76	2.11	2.24	2.82	2.97	1.98	2.52
	M_3	2.55	2.58	2.63	2.17	2.76	2.83	1.95	2.50
	Mean (C)	2.60	2.63	2.38	2.19	2.76	2.85	1.96	
CD at 5%		C = 0.048		M = 0.031			C × M = 0.083		

Note: M_1 - September branch bending, M_2- October branch bending, M_3 - December branch bending, C_1 - NAA@100 ppm, C_2 - NAA@200 ppm, C_3 - Ethrel@200 ppm, C_4 - Ethrel@400 ppm, C_5 - GA_3@150 ppm, C_6 - GA_3@200 ppm, and C_0 - Control.

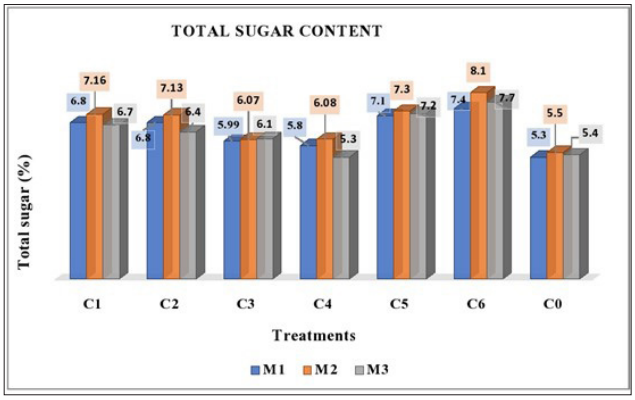

Figure 2: Graphical representation of branch bending and PGR application on total sugar content.

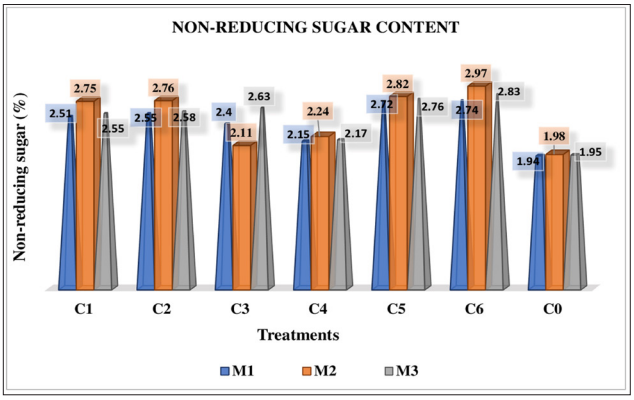

Figure 4: Graphical representation of branch bending and PGR application non-reducing sugar content.

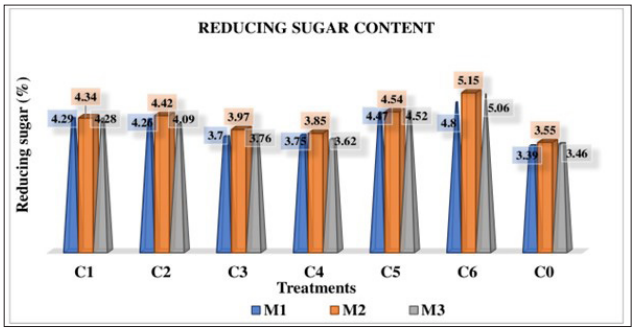

Figure 3: Graphical representation of branch bending and PGR application on reducing sugar content.

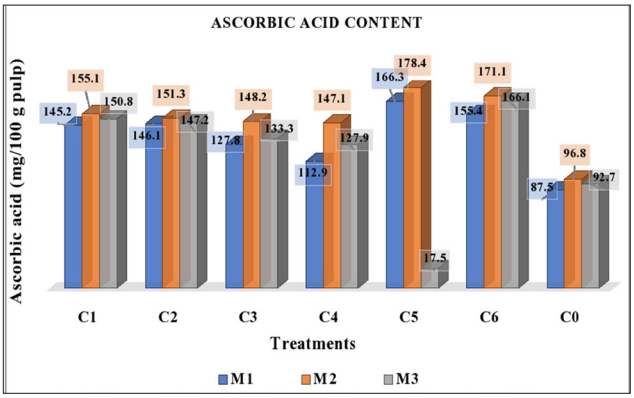

Figure 5: Graphical representation of branch bending and PGR application on ascorbic acid content.

for carbohydrates to build up could also be another reason [22]. Furthermore, branch bending certainly promotes sunlight transmission beneath the canopy raises photosynthesis efficiency [23] and discourages the effect of apical dominance but its effect was seen more pronounced in October could be because of the absence of natural precipitation which restricts the dilution of sugars present in fruits.

Ascorbic acidity and titrable acidity

Branch bending procured substantial values in October month (M_1) while September (M_2) displayed abrupt performances for both ascorbic (149.75 mg/100 g pulp) and titrable acidity (0.338%). Data present in table 2 displays that with the increase in sugars, a remarkable decrease in acidity was noticed. GA_3 application influenced the increase in ascorbic acid value (171.18 mg/100 g of pulp) with consecutive decrease in titrable acidity percent (0.25%) at concentration 150 ppm (C_5). As shown in figure 5 and figure 6 fruit associated with October branch bending and GA_3 spray (T_{11}) exerted a better percentage for both parameters with mean values of 178.42 mg/100 g of pulp and 0.25% respectively whereas, control recorded the lowest performance 87.53 mg/100 g of pulp

Table 2: Effect of branch bending and PGR application on ascorbic acid and titrable acidity content.

Parameter	M	C_1	C_2	C_3	C_4	C_5	C_6	C_0	Mean (C)
Ascorbic acid (mg/100 g of pulp)	M_1	145.23	146.1	127.83	112.96	166.36	155.4	87.53	134.49
	M_2	155.16	151.33	148.23	147.1	178.42	171.18	96.86	149.75
	M_3	150.83	147.2	133.36	125.83	170.53	166.1	92.73	140.94
	Mean (C)	150.41	148.21	136.47	128.63	171.77	164.22	92.37	
CD at 5%		C = 1.828		M = 1.197			C × M = 3.166		
Titrable acidity (%)	M_1	0.36	0.38	0.41	0.43	0.34	0.32	0.45	0.38
	M_2	0.32	0.33	0.37	0.4	0.25	0.28	0.41	0.33
	M_3	0.33	0.36	0.39	0.41	0.29	0.31	0.42	0.36
	Mean (C)	0.33	0.36	0.39	0.41	0.29	0.30	0.42	
CD at 5%		C = 0.011		M = 0.007			C × M = 0.019		

Note: M_1- September branch bending, M_2- October branch bending, M_3 - December branch bending, C_1- NAA@100 ppm, C_2- NAA@200 ppm, C_3- Ethrel@200 ppm, C_4- Ethrel@400 ppm, C_5- GA_3@150 ppm, C_6 - GA_3@200 ppm, and C_0- Control.

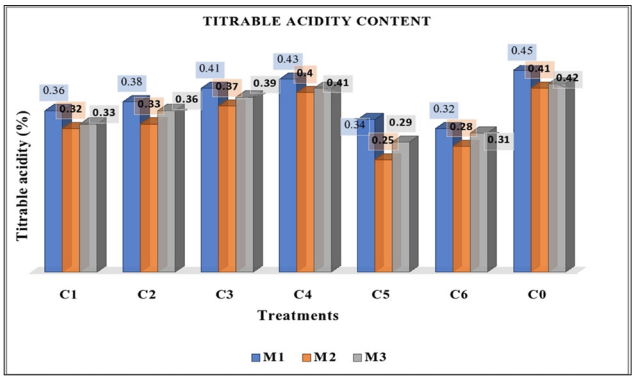

Figure 6: Graphical representation of branch bending and PGR application on titrable acidity content.

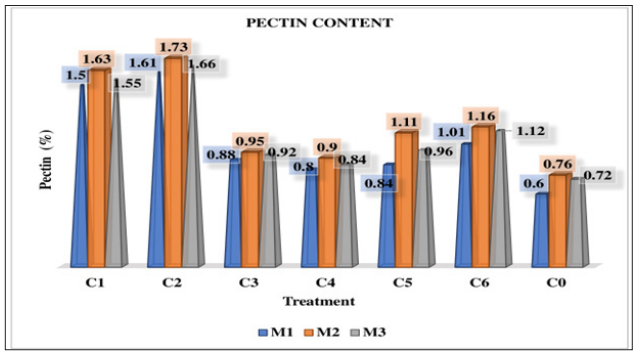

Figure 7: Graphical representation of branch bending and PGR application on pectin content.

and 5.33%. in the month of September. The results are similar to the studies of Gupta et al. [24] and Lal and Das [2].

The interaction between the treatments and their combination was found to be significant. The explanation for the rise in ascorbic acid levels in fruits through the application of GA_3 treatment could be from the continuous production of glucose-6-phosphate during the fruit's maturation process as this compound is believed to serve as the precursor for vitamin C whilst the decrease in acidity observed in treatments involving the application of growth regulators could potentially be attributed to the swift consumption of organic acids during the ripening process through respiration, as documented by Thakur et al. [25].

Pectin content

Amongst the branch bending performed in three months, October (M_1) witnessed an enormous spike in the pectin percentage, at an average value of 1.17% while September (M_3), on the other hand, had a comparatively minor impact, with an average value of 1.04%. As shown in table 3, in terms of plant hormones performance, NAA at 200 ppm (C_2) delivered the most desirable percentage for pectin content (1.66%), while ethrel at 400 ppm (C_4) imparted the most minor effect with the outcome (0.84%). Moreover, the treatment (T_9) had the highest pectin percentage (1.73%), whereas (T_7) had the lowest (0.66%) (Figure 7). Increased levels of PGRs such as NAA may have contributed to the breakdown of pectin compounds within the middle lamella, resulting in an increase in pectin content. Similarly, Kumar and Rattanpal [26] discovered that NAA spraying in guava boosted pectin content. Data collected emphasize the strong relationship between branch bending and plant growth hormone spray.

Conclusion

It was evident through the observation procured, that guava fruits had shown positive results when branch bending was performed in the month of October for all biochemical parameters. Among all the plant hormones applied, GA_3 had left promising results on TSS, total sugar, and reducing and non-reducing sugar with a concentration of 200 ppm although ascorbic and titrable acidity had gained optimum values with a slight reduction of the concentration of GA_3 that is at 150 ppm. Unlike all attributes NAA@200 influenced pectin content at 200 ppm spray. However, all the treatments formed in combination with branch bending carried out in different months along the PGR application were found to be significant in interaction. Throughout all the treatments established in the present study, almost all the parameters had a positive correlation with GA_3 spray at 200 sprays plus October branch bending. To summarise, the study is ample to standardize GA_3 spray as a quality enhancer and branch bending as a better crop regulation alternative for qualitative growth of guava fruit in the off-season.

Acknowledgements

Authors involved in research findings gracefully acknowledge the overwhelming amount of support received in the form and guidance and financial support by the Lovely Professional University, the Department of Horticulture Teaching, and Laboratory staff.

Conflict of Interest

None.

Table 3: Effect of branch bending and PGR application on pectin content.

Parameter	M	C_1	C_2	C_3	C_4	C_5	C_6	C_0	Mean (C)
Pectin content (%)	M_1	1.5	1.61	0.88	0.8	0.84	1.01	0.66	1.04
	M_2	1.63	1.73	0.953	0.9	1.11	1.16	0.76	1.17
	M_3	1.55	1.66	0.92	0.84	0.96	1.12	0.72	1.11
	Mean (C)	1.56	1.66	0.92	0.84	0.97	1.1	0.71	
CD at 5%		C = 0.028		M = 0.018		C × M = 0.049			

Note: M_1- September branch bending, M_2- October branch bending, M_3- December branch bending, C_1- NAA@100 ppm, C_2- NAA@200 ppm, C_3 - Ethrel@200 ppm, C_4- Ethrel@400 ppm, C_5- GA_3@150 ppm, C_6 - GA_3@200 ppm, and C_0 - Control.

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