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Research Article

Combined influence of shoot bending and plant growth regulators on morphological traits of Guava cv. Allahabad Safeda

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Abstract

Guava (*Psidium guajava* L.) is a widely cultivated tropical fruit crop consumed raw and also in the form of processed products. Winters in Punjab show a drop in temperature, which hardens the fruit. Therefore, manipulation of the flowering season is desirable. Hence, the present study aimed to select an adequate combination of plant hormones and branch bending to amplify the quantitative traits in Guava cv. Allahabad Safeda. For combinations, three months for branch bending viz., August, September and October and three plant hormones: Naphthaleneacetic acid, Ethrel, and Gibberellins, with two different concentrations each (NAA@100ppm, NAA@200ppm, Ethrel@200ppm, Ethrel@400ppm, GA_3@100ppm, GA_3@150ppm were selected. The experimental layout was planned in two two-factor randomized block design (RBD) with twenty-one treatments. In the case of branch bending months, (M_1) August branch bending gained ideal values in comparison with (M_2) September and (M_3) October. Combination of NAA at the rate of 200ppm with August branch bending (T_2) gave more pronounced results for almost all vegetative parameters, while amongst plant hormones NAA at 200 ppm (C_2) enhanced results for Canopy spread (N-S), canopy spread (E-W), length of internode and days for the emergence of new leaf 0.837m and 0.803m, 14.1cm and 27.33 respectively. Results vividly provide a strong base for selecting a combination of NAA spray at 200ppm concentration and August month for branch bending to uplift morphological traits in guava. Thus, these findings will favour horticulture breeders and farmers in harvesting profitable gains for field parameters by selecting a better combination of PGR and crop regulation measures from the off-season.

Keywords: August, Branch bending, Crop regulation, Naphthaleneacetic acid (NAA), Plant hormones

INTRODUCTION

The guava (*Psidium guajava* L), also referred to as the "Apple of the tropics" or "Poor man's apple", is one of the most significant fruit crops in the Myrtaceae family (Baloda *et al.*,2018). Although the exact origin is undetermined, guavas are believed to have evolved in tropical America, primarily Mexico and the Caribbean, where they have become recognized as the "sand plum." Guava has a documented history from the fifteenth century and is now commercially cultivated in several countries, including India, Mexico, Hawaii, and Egypt (Hussain *et al.,* 2021). Formerly *P. poniferum* and *P. pyriferum* had been regarded as two distinct species. But they are now acknowledged as the same species with just slight differences. More than 150 guava species are grown worldwide (Abreu *et al.,*2012). In India, guava cultivation occupies around 287 thousand hectares and generates 4304 thousand MT (NHB,2016). The state of Uttar Pradesh has India's largest guava production area(Abreu *et al.,*2012). Punjab covers an area of 7.8 ha with production of 171.0' MT (NHB,2016). In Ayurveda, it is commonly referred to as *tridosha nashaka* (Immunity booster drink) and is recommended in *atyagni* (excessive digestion). The leaves, bark, fruits, and roots of guava relieve coughs, fevers, diarrhoea, bowel movements, foul breath, dental problems, and other health issues furthermore, the leaves can be consumed for harvesting dyes and tannin (Hiwale *et al.*,2015), while the leaf extracts exhibit biological activity such as anticancer, antidiabetic, antioxidant, antidiarrheal, antibacterial, lipid-lowering, and hepatoprotective properties (Kumar *et al*.,2021b).Guava exhibits flowering on the current season's new growth despite the fruit being accessible throughout the year.

Plant growth regulators (PGRs) possess significant market potential and are crucial in enhancing worldwide crop output by alleviating environmental stressors and maximizing yields without compromising sustainability. Their integration into contemporary farming practices has become indispensable, fostering sustainable agricultural growth (Wu *et al*.,2024). PGRs like Naphthalene acetic acid (NAA) and Gibberellic acid (GA_3) find application in fruit crops primarily to enhance fruit attributes. NAA involvement in the water relationship of cells instigated the translocation of major and minor nutrients, which shows an increase in the number of leaves (Kumar *et al.,* 2021a). NAA spray at 150 ppm was achieved to increase plant height and GA_3 boosts division of cells and expansion, enhancing stem length in Guava (Gangwar *et al*., 2023). Leaves are regarded to contain the primary structures that transform externally given ethephon into ethylene (Hifny *et al.,*2017). Elongation in the stem length was witnessed with GA_3 application at 1 µM (Yofune *et al.,*2023). Therefore, the pivotal benefits of PGRs make them a subject of interest for fruit breeders.

The guava flowering season occurs naturally in three distinct periods: February-March (Ambe Bahar), June-July (Mrig Bahar), and October-November (Hasth Bahar). The corresponding harvest occurs throughout the rainy, winter, and spring seasons (Liu *et al.,*2021). The quality of guavas is greatly influenced by temperature and humidity; winter produces better fruits than the wet season. The lack of warmth in the winter months in subtropical regions such as Punjab, Haryana, Uttar Pradesh, the northern parts of West Bengal, and Bihar makes commercial production difficult. It requires about 200 days from flowering to harvest. The chilly temperatures in December and January inhibit guavas from maturing naturally on the tree, resulting in solid fruit. (Mishra *et al*.,2020). Hence, crop regulation is required as it allows trees to relax and produce more during flushes (Sharma *et al*.,2015), while higher plants derive energy from photosynthesis. It is crucial for them to position their leaves to ensure adequate sunlight absorption (Yofune *et al*.,2023). Various techniques are employed to enhance both production and fruit quality through crop regulation. These methods encompass manual thinning, stooling, application of plant hormones, chemical thinning, selective harvesting, training, summer and winter pruning, and measures to prevent pre-harvest fruit drop (Lalhriatpuia *et al*.,2021). Bending has been suggested as a substitute for pruning to encourage early fruit revenue and regulate tree size (Lauri *et al.,*2001). The bending of branches can potentially disrupt the downward transport of auxin in plants, consequently altering the levels of cytokinin and strigolactone in dormant lateral buds, prompting their reactivation (Mishra *et al*.,2020). Several experiments are conducted to analyse the effect of bending on vegetative growth, referred to as gravimorphic reactions, which resulted in short shoots, mainly reducing the internodes. (Lauri *et al*., 2001).

The key flowering periods in North India are observed from April to May and August to September (Kumar *et al*.,2021a) (; Ito *et al*., 1999).There is limited documentation on manipulating the flowering period (August to September) to achieve good vegetative growth in the Punjab region. Therefore, an experiment was conducted to achieve a greater number of lateral shoots through the exposure of branch bending with PGR spray on Guava cv. Allahabad Safeda crop. The objective of the present study was to offer a summary of the influence of these on the vegetative aspects of guava cultivation.

MATERIALS AND METHODS

Experimental site

The present experiment was conducted during the consecutive years 2022 and 2023 in Horticulture Farm, School of Agriculture Lovely Professional University Phagwara, Punjab.

Experimental material and design

Six-year-old Allahabad Safeda cultivar was chosen and planted at a 6×5m distance in a guava orchard. Two factorial randomized block designs (RBD) were adopted as experimental designs with three replications.

Each replication had one plant, and each trial month had twenty-one plants. A total of sixty-three plants were selected and tagged during the whole experiment.

Cultural practices

25-40 Kg/tree Farm Yard Manure (FYM), Urea 300g/tree, Single super phosphate 1500-2000g/tree and Muriate of potash 600-1000g/tree was applied. FYM was applied in May, while inorganic fertilizers were given in split dosages. Half of the dose was given one month before the bending operation, while the other half was provided after fifteen days of bending operation in August, September, and October. Based on agrometeorological data, the minimum and maximum temperatures and relative humidity for August, September, and October were as follows: In August, temperatures ranged from 36.9°C to 25.9°C with 75.3% relative humidity, and rainfall was 0.9 mm. In September, temperatures ranged from 35.6°C to 24.2°C with 72.1% relative humidity, and rainfall was 0.4 mm. In October, temperatures ranged from 32.2°C to 20.4°C with 54.7% relative humidity, and there was 0mm i.e., no rainfall. Implementing cultural practices and fertilizer input were followed per Punjab Agriculture University (PAU) recommendation. Irrigations were provided in 2 to 3 rounds, especially at the time of fruit set and flowering; additionally, 0.7kg of rice paddy per tree was applied for weed control. Bending treatments were administered on the fourth week of each month throughout the morning hours (8:00 to 10:00 A.M.).

Shoot bending procedure

Defoliating shoots accomplished bending, and the defoliated branches were forced to bend using ropes linked to pegs in the soil until new flushes emerged. Bending operations were initiated 45-60 days before flowering. The leaves, short branches, and flowers are removed, leaving 10-12 inches of terminal twig intact. The shoots were bent down by connecting the tips to a peg placed into the ground. When the new shootlets were about 1cm in length, the bent branches were loosened**.**

Treatment details

Three months were chosen for bending operation, (M_1) August, (M_2) September and (M_3) October, and three PGRs with two varied concentrations were prepared viz., (C_1) NAA@100ppm, (C_2) NAA@200ppm, (C_3) Ethrel@200ppm, (C_4) Ethrel @400ppm, (C_5) GA_3@100ppm and (C_6) GA_3 @150ppm), M_1: Branch bending in August Month, M_2: Branch bending in September month, M_3: Branch bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_7: Control). A total of twenty-one treatments in combination were formulated. Experimental details are shown in Table 1 and 2.

Observations details

All the field observations were recorded after 60 days of treatment. Canopy spread was measured in both the N-S and E-W directions using a measuring tap in meters. The canopy height was assessed from the top leaf of the main stem to the bottom last leaf, recorded in meters. Stem girth was documented by drawing a circular line with white paint 20 cm above the ground, using a digital vernier, and measuring it in square centimetres. The length and width of leaves, internode length, and shootlet length were also measured with a vernier calliper in centimetres. Photosynthetic leaf area was calculated by selecting the third pair of leaves from the shoot apex; 10 leaf pairs were collected, the average leaf area was determined, and this value was multiplied by the average number of leaves. The number of leaf pairs per shoot and the number of shoots per branch were counted manually. Additionally, the days taken for the emergence of new shootlets and new leaf emergence were recorded from the start of the experiment.

Statistical analysis

The experimental design was a Randomized block design (RBD) with three replications. The data obtained was analyzed using SPSS Statistics software version 20. One-way analysis of variance (ANOVA) was used to evaluate significant differences in parameters studied in different treatments. Statistical significance, presented using letters in the tables below, was assumed at a level of 5% ($p < 0.05$).

Table 1. Detail of plant growth regulators and branch bending months

Branch bending months	**PGR (Concentration in ppm)**						
	C_1 NAA@100	**C_2 NAA@200**	**C_3 Ethrel@200**	**C_4 Ethrel@400**	**C_5 GA_3@100**	**C_6 GA_3@150**	**C_7 Control**
	Treatments (M×C)						
M_1(August)	T_1	T_2	T_3	T_4	T_5	T_6	T_7
M_2(September)	T_8	T_8	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}
M_3(October)	T_{15}	T_{16}	T_{17}	T_{18}	T_{19}	T_{20}	T_{21}

Table 2. Detail of treatments

Treatments	Interaction ($M_n \times C_n$)	Plant growth hormone Concentration (ppm)	Treatments	Interaction ($M_n \times C_n$)	Bending Months
T_1	M_1C_1	C_1: NAA@100	T_1	M_1C_1	August
T_2	M_1C_2	C_2: NAA@200	T_2	M_1C_2	August
T_3	M_1C_3	C_3: Ethrel@200	T_3	M_1C_3	August
T_4	M_1C_4	C_4: Ethrel@400	T_4	M_1C_4	August
T_5	M_1C_5	C_5: GA_3@100	T_5	M_1C_5	August
T_6	M_1C_6	C_6: GA_3@150	T_6	M_1C_6	August
T_7	Control	C_7: Control	T_7	M_1C_7	August
T_8	M_2C_1	C_1: NAA@100	T_8	M_2C_1	September
T_9	M_2C_2	C_2: NAA@200	T_9	M_2C_2	September
T_{10}	M_2C_3	C_3: Ethrel@200	T_{10}	M_2C_3	September
T_{11}	M_2C_4	C_4: Ethrel@400	T_{11}	M_2C_4	September
T_{12}	M_2C_5	C_5: GA_3@100	T_{12}	M_2C_5	September
T_{13}	M_2C_6	C_6: GA_3@150	T_{13}	M_2C_6	September
T_{14}	Control	C_7: Control	T_{14}	M_2C_7	September
T_{15}	M_3C_1	C_1: NAA@100	T_{15}	M_3C_1	October
T_{16}	M_3C_2	C_2: NAA@200	T_{16}	M_3C_2	October
T_{17}	M_3C_3	C_3: Ethrel@200	T_{17}	M_3C_3	October
T_{18}	M_3C_4	C_4: Ethrel@400	T_{18}	M_3C_4	October
T_{19}	M_3C_5	C_5: GA_3@100	T_{19}	M_3C_5	October
T_{20}	M_3C_6	C_6: GA_3@150	T_{20}	M_3C_6	October
T_{21}	Control	C_7: Control	T_{21}	M_3C_7	October

RESULT AND DISCUSSION

Canopy spread (N-S), canopy spread (E-W), canopy height, and stem girth

Maximum canopy spread for N-S and E-W, canopy height, and stem girth were obtained from NAA with 200ppm concentration (C_2) 0.837m, 0.803m, 0.55m, and 28.77cm. The present results displayed that NAA performed better concerning the above parameters, followed by GA_3 and Ethrel. The higher vegetative development observed with NAA at 200ppm (M_2) could perhaps be attributed to the synthesis of nitrogen in protoplasm and an increase in the synthesis of amino acids and auxin. Similar results were addressed by El-Naby *et al.* (2019) for apricot cv. 'Carino' with NAA application. Khan *et al.* (2023) reviewed that increased meristematic growth due to auxin leads to enhanced vegetative development due to the higher rate of cell division and elongation in the meristem regions.Amongst all the months in which branch bending was performed (M_1) August gained substantial data for the above traits with mean values of 0.673m, 0.677m, 0.487m, and 27.28 in the guava crop(Table 3). Increasing relative humidity and temperature has played a pivotal role in escalating the photosynthetic rate and promoting enough transpiration, water, and nutrient uptake to favour better vegetative growth. (Rawson *et al*., 1977). The reason for the highest observations in August month bending (M_1) could be its rising temperature and RH % (Max. 36.9°C to Min. 25.9°C with 75.3% relative humidity). Lauri *et al.* (2001) recorded a pivotal rise in lateral shoot formation in pear fruit following branch bending, attributed to the reduction in apical dominance. Additionally, they marked elevated fruit growth alongside improvements in stem-related traits. With increased stem-related traits, the fruit-bearing will evolve in quality and quantity. A combination (T_2) of branch bending performed in August (M_1) plus PGR spray of NAA at 200ppm (C_2) gained highest observations with values of 0.850m, 0.830m, 0.570m, and 29.73cm, respectively whilst the lowest was recorded in control of September and October with minimum variation, i.e., (T_{14}) and (T_{21}) for Canopy spread (N-S) 0.32m, (T_{21}) Canopy spread (E-W) 0.28m, (T_{21}) Canopy height 0.34m, (T_{14}) Stem girth 24.3 cm^2 in guava. Canopy spreads from both directions N-S and E-W, Canopy height and stem girth are important aspects of plant architecture that directly or indirectly prompt plants to absorb sunlight and thereby help in the photosynthesis process. Treatment combination (T_2) of branch bending performed in August (M_1) month plus NAA @200ppm (C_2) portrayed better performances in comparison with that of control. Increase in canopy-related traits in guava, favors microclimate by lowering the higher temperature and conserving moisture within the crop environment, which enhances growth altogether.

Number of leaf pairs per shoot, photosynthetic leaf area, length of leaf and width of the leaf

In the present study, amongst PGR applied NAA performed well with 200ppm concentration (C_2) with a mean value of 9.24, 779.56cm^2, 8.3cm and 5.4cm for number of leaf pair per shoot, photosynthetic leaf area, length and width of leaf, respectively. One potential explanation for the effectiveness of NAA could be its ability to enhance amylase activity, membrane permeability, and the accumulation of energy-rich phosphate. NAA @200ppm(C_2) results fall into similar findings as reported earlier (Sharma *et al*.,2015; Lakshmipathi *et al*.,2014) , where GA_3, Ethrel, and NAA notably augmented the leaf area of the Bhaskara cashew variety. In the present study, the observed increase in leaf area due to NAA may be attributed to their promotion of leaf expansion and cell division in higher plants. On the other hand, August month branch bending (M_1) gave positive results for all leaf-related traits, i.e., for the number of leaf pairs per shoot (7.93), PLA (980.1cm^2), length of leaf (8.3cm) and width of leaf (5.5cm) [Table 4]. Branch bending alters the plant's hormonal balance, activating the dormant buds and giving more lateral growth in return. Bending in August certainly influenced the results due to the C:N ratio increase. Zhang *et al.* (2023) examined maximum vegetative growth in peaches through bending operation, where they emphasized that an increased meristematic activity significantly boosts vegetative growth, attributed to enhanced nutrient uptake and more efficient resource allocation within the plant. The finding falls parallel with August bending results (M_1). Moreover , combination (T_2) of august branch bending (M_1) along with NAA with 200ppm (C_2) spray proved to be efficient in performing for number of leaf pair per shoot (9.74), PLA (991.7 cm^2) while length of leaf and width of leaf performed in contradiction (T_9) treated tree, gained more values in September month branch bending (M_2) plus NAA @200ppm (C2), 9.5cm and 6.3cm respectively and least observations were collected from control (T_{21}) viz., number of leaf pair per shoot (6.3), photosynthetic leaf area (459.1cm^2), length of leaf (5.9cm) and width of leaf (3.4cm) in guava. Maximum temperature values for August (36.9^{0}C) and September (35.6^{0}C) were almost the same, which might serve as a plausible explanation for the parallel effectiveness of branch bending in (M_2) September and August (M_1). The number of leaf pairs per shoot, photosynthetic leaf area, and length and width of the leaf

Table 3. Effect of branch bending and PGR application on canopy spread (N-S), canopy spread (E-W), canopy height, and stem girth

Parameters	Branching bending (Month)	Plant growth Hormones (ppm)							Mean (C)
		NAA		Ethrel		GA$_3$		Control	
		C_1 (100)	C_2 (200)	C_3 (200)	C_4 (400)	C_5 (100)	C_6 (150)	C_7 (Control)	
Canopy spread (N-S) (m)	M_1(August)	0.800	0.850	0.630	0.650	0.650	0.790	0.340	0.673
	M_2(September)	0.790	0.830	0.620	0.630	0.730	0.750	0.320	0.667
	M_3(October)	0.760	0.830	0.610	0.630	0.720	0.740	0.320	0.659
	Mean(M)	0.783	0.837	0.620	0.637	0.700	0.760	0.327	
CD at 5 %	Factor (M): N/A		Factor (C): 0.019			Factor(M×C): 0.033			
Canopy spread (E-W) (m)	M_1(August)	0.800	0.830	0.640	0.690	0.700	0.760	0.320	0.677
	M_2(September)	0.790	0.810	0.630	0.680	0.690	0.710	0.310	0.660
	M_3(October)	0.750	0.770	0.620	0.640	0.650	0.730	0.280	0.634
	Mean(M)	0.780	0.803	0.630	0.670	0.680	0.733	0.303	
CD at 5 %	Factor (M): 0.010		Factor (C): 0.015			Factor(M×C):N/A			
Canopy Height (m)	M_1(August)	0.560	0.570	0.460	0.470	0.480	0.490	0.380	0.487
	M_2(September)	0.540	0.550	0.430	0.470	0.450	0.480	0.350	0.467
	M_3(October)	0.520	0.530	0.410	0.420	0.420	0.440	0.340	0.440
	Mean(M)	0.540	0.550	0.433	0.453	0.450	0.470	0.357	
CD at 5 %	Factor (M): 0.008		Factor (C): 0.012			Factor(M×C):N/A			
Stem girth (cm)	M_1(August)	28.860	29.730	26.440	24.330	27.880	28.440	25.320	27.286
	M_2(September)	27.990	29.720	27.330	25.440	26.320	25.330	24.340	26.639
	M_3(October)	27.910	26.880	28.330	27.390	27.430	26.320	24.890	27.021
	Mean(M)	28.253	28.777	27.367	25.720	27.210	26.697	24.850	
CD at 5 %	Factor (M): 0.463		Factor (C): 0.707			Factor(M×C): 1.225			

Where, M_1: Branch bending in August Month, M_2: Branch bending in September month, M_3: Branch bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_7: Control play a vital role in photo assimilation, light interception, transpiration, and stomatal conductance, enhancing plant productivity.

New shoots per branch, length of shootlets, and length of internode

In a recent study, an increase in new shoots per branch, length of shootlets, and length of internode was established by applying NAA @200ppm (C_2) followed by GA_3 and Ethrel with mean values of 14.1, 28.83cm, and 3.14cm, respectively. NAA, being an auxin, has a humungous part in organogenesis, vascular tissue differentiation, tropism, and cellular-level cell division (Tamang *et al.,*2021). Furthermore, Khan *et al.* (2023) stated that auxin is crucial in initiating leaf development. During this process, auxin synthesis is observed to increase the size of the shoot apical meristem, thereby enhancing subsequent growth and development. On the other hand, new shoots per branch (14.81) and length of internode (3.17cm) displayed escalation for August month branch bending (M_1) whereas, September branch bent (M_2) plants gave the highest mean value for the length of shootlets (25.64cm) in present experiment bending conducted in August and September displayed substantial outcomes with subtle variation could be due to the elevated atmospheric temperature (36.9^{0}C) and 35.6^{0}C), and relative humidity (75.3 % and 72.1%) respectively can be the reason. Consequently, a majority of the induced shoots exhibited increased internode length. Futhermore, treatment (T_2) in a combination of August month branch bending (M_1) and NAA spray @200ppm (C_2) had a positive influence

Table 4. Effect of branch bending and PGR application on the number of leaf pairs per shoot, photosynthetic leaf area, length of leaf and width

Parameters	Branching bending (Month)	Plant growth Hormones (ppm)							Mean (C)
		NAA		Ethrel		GA_3		Control	
		C_1 (100)	C_2 (200)	C_3 (200)	C_4 (400)	C_5 (100)	C_6 (150)	C7 (Control)	
Number of leaf Pair per shoot	M_1(August)	8.560	9.740	7.300	7.500	7.700	7.910	6.800	7.930
	M_2(September)	8.240	9.100	6.700	6.900	7.100	7.830	6.500	7.481
	M_3(October)	8.110	8.900	6.600	6.890	6.960	7.740	6.300	7.357
	Mean(M)	8.303	9.247	6.867	7.097	7.253	7.827	6.533	
CD at 5 %	Factor (M): 0.128		Factor (C): 0.196			Factor(M×C): N/A			
Photosynthetic leaf area per shoot (cm^2)	M_1(August)	987.70	991.70	973.20	975.87	979.30	981.73	971.20	980.10
	M_2(September)	862.73	867.83	858.20	859.80	861.87	862.60	853.10	860.88
	M_3(October)	475.03	479.13	462.40	464.70	469.53	471.90	459.10	468.83
	Mean(M)	775.16	779.56	764.60	766.79	770.23	772.08	761.13	
CD at 5 %	Factor (M): 12.52		Factor (C): N/A			Factor(M×C): N/A			
Length of leaf (cm)	M_1(August)	8.800	8.900	7.900	8.000	8.500	8.600	7.500	8.314
	M_2(September)	9.200	9.500	8.500	8.700	8.900	8.800	8.100	8.814
	M_3(October)	6.500	6.700	6.000	6.100	6.300	6.400	5.900	6.271
	Mean(M)	8.167	8.367	7.467	7.600	7.900	7.933	7.167	
CD at 5 %	Factor (M): 0.123		Factor (C): 0.188			Factor(M×C): N/A			
Width of leaf (cm)	M_1(August)	5.700	5.900	5.200	5.300	5.600	5.800	5.000	5.500
	M_2(September)	6.100	6.300	5.500	5.600	5.700	6.000	5.100	5.757
	M_3(October)	4.200	4.000	3.600	3.500	3.900	3.700	3.400	3.757
	Mean(M)	5.333	5.400	4.767	4.800	5.067	5.167	4.500	
CD at 5 %	Factor (M): 0.088		Factor (C):0.134			Factor(M×C): 0.233			

Where, M_1: Branch bending in August Month, M_2: Branch bending in September month, M_3: Branch bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_7: Control)

Table 5. Effect of branch bending and PGR application on new shoots per branch, length of shootlets, length of internode

Parameters	Branching bending (Month)	Plant growth Hormones (ppm)							Mean (C)
		NAA		Ethrel		GA_3		Control	
		C_1 (100)	C_2 (200)	C_3 (200)	C_4 (400)	C_5 (100)	C_6 (150)	C_7 (Control)	
New shoots per branch	M_1(August)	15.900	16.700	12.800	13.700	14.800	14.800	15.000	14.814
	M_2(September)	13.800	14.300	9.200	10.800	12.200	12.200	12.800	12.186
	M_3(October)	10.800	11.300	7.300	7.900	9.000	9.000	9.400	9.243
	Mean(M)	13.500	14.100	9.767	10.800	12.000	12.000	12.400	
CD at 5 %	Factor (M): 0.215			Factor (C): 0.328			Factor(M×C): 0.568		
Length of shootlets (cm)	M_1(August)	27.000	29.000	21.000	20.880	25.000	23.000	19.770	23.664
	M_2(September)	28.000	29.540	24.000	23.400	27.000	26.000	21.540	25.640
	M_3(October)	25.000	27.950	20.440	19.650	23.000	22.000	15.760	21.971
	Mean(M)	26.667	28.830	21.813	21.310	25.000	23.667	19.023	
CD at 5 %	Factor (M): 0338			Factor (C): 0.516			Factor(M×C): 0.893		
Length of inter-node (cm)	M_1(August)	3.220	3.250	3.170	3.130	3.200	3.210	3.040	3.174
	M_2(September)	3.190	3.210	3.110	3.100	3.160	3.140	3.000	3.130
	M_3(October)	2.940	2.980	2.830	2.790	2.910	2.960	2.670	2.869
	Mean(M)	3.117	3.147	3.037	3.007	3.090	3.103	2.903	
CD at 5 %	Factor (M): 0.041			Factor (C): 0.063			Factor(M×C): N/A		

Where, M_1: Branch bending in August Month, M_2: Branch bending in September month, M_3: Branch bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_7: Control

on new shoot per branch, length of internode with observations 16.70cm and 3.25cm, respectively, while the length of shootlets was highest with (T_9) treated pants 29.54cm, i.e., for a combination of September month branch bending plus NAA @200ppm in contrast, inferior observations were recorded from control (T_{21}) new shoots per branch (9.4), length of shootlets (15.7cm), and length of internode (2.6cm). [Table 5]. The combination has vividly optimized shoot-related traits in the guava crop, which can achieve balanced growth with maximum light capture, nutrient uptake, and overall productivity.

Days taken for the emergence of new shootlets and days taken for the emergence of new leaf

The present investigation portrayed that NAA @200ppm (C_2) spray significantly reduced the days taken for the emergence of new shootlets and new leaf emergence, with mean values of 25.66 and 27.33 days, respectively. Amongst all PGR applied, the reduction of days taken to emerge new shootlets and leaves by NAA spray might be because of its direct involvement in cell division, expansion, and elongation in the apical area. Auxin affects cell elongation by uplifting osmotic pressure and cytoplasm permeability to water. Sharma *et al.,* (2015). On the other hand, August month branch bending (M_1) marked the decrease in the days taken for emergence for both the traits viz., 27 and 28.8 days. High temperature and humidity in August (36.9^{0}C;75.3%) compared to October (32.2^{0}C;72.1%) could be an appropriate articulation for reducing the number of days taken for the emergence of new shootlets and days taken for new leaf emergence. The study conducted by Tamang *et al.* (2021) on guava supports similar outcomes, where higher temperatures from April to September gained better vegetative val-

Table 6. Effect of branch bending and PGR application on days taken for emergence of new shootlets and days taken for emergence of new leaf.

Parameters	Branching bending (Month)	Plant growth Hormones (ppm)							Mean (C)
		NAA		Ethrel		GA_3		Control	
		C_1 (100)	C_2 (200)	C_3 (200)	C_4 (400)	C_5 (100)	C_6 (150)	C_7 (Control)	
Days taken for emergence of new shootlets	M_1(August)	23.000	21.000	29.000	30.000	25.000	27.000	34.000	27.000
	M_2(September)	27.000	26.000	31.000	33.000	28.000	29.000	36.000	30.000
	M_3(October)	29.000	30.000	35.000	37.000	32.000	34.000	38.000	33.571
	Mean(M)	26.333	25.667	31.667	33.333	28.333	30.000	36.000	
CD at 5 %	Factor (M): 0.506		Factor (C): 0.773			Factor(M×C): 1.338			
Days takes for emergence of new leaf	M_1(August)	25.000	23.000	31.000	33.000	27.000	27.000	36.000	28.857
	M_2(September)	29.000	28.000	34.000	35.000	30.000	30.000	40.000	32.286
	M_3(October)	33.000	31.000	37.000	40.000	35.000	35.000	42.000	36.143
	Mean(M)	29.000	27.333	34.000	36.000	30.667	30.667	39.333	
CD at 5 %	Factor (M): 0.622		Factor (C): 0.950			Factor(M×C): N/A			

Where, M_1: Branch bending in August Month, M_2: Branch bending in September month, M_3: Branch bending in October month; C_1: NAA@100ppm, C_2: NAA@200ppm, C_3: Ethrel@200ppm, C_4: Ethrel@400ppm, C_5: GA_3@100ppm, C_6: GA_3@150ppm, C_7: Control

ues. While, the exposure of (T_1) on the guava crop showed earliness for the emergence of shootlets and new leaves with observations collected at 21 and 23 days, while the least data was achieved from control (T_{21}), i.e., 38 and 42 days respectively [Table 6]. A combination of (T_2) August month branch bending with NAA at 200ppm of concentration has proven to cause earliness compared to individual NAA and branch bending treatment, which can lead to harvesting before time and certainly would avoid fruit scarcity in the off-season.

Conclusion

The present study on a combination of PGR and branch bending performed in different month in guava cv. Allahabad Safeda concluded that within all plant hormones applied NAA @200ppm (C_2) concentration performed best for all traits viz., stem girth (28.77cm), PLA (779.56cm^2), new shoots per branch (8.36) and days required for emergence of new shootlets (28.83). On the other hand, branch bending months August (M_1) and September (M_2) performed well for all vegetative traits of guava compared with October bent shoots (M_3) PLA (980.1 cm^2). Treatment (T_2), a combination of August bent shoots (M_1) and NAA application at 200ppm (C_2), gave positive results in all parameters except for new shoots per branch, length of shootlets, and length of internode. A combination of treatments gave better results than PGR or branch bending alone. Although there are enormous works illustrating the beneficial roles of branch bending and plant hormones individually, the combined exposure has not yet been witnessed. The present study deduced that NAA @200ppm (C_2) with branch bending in August (M_1) promoted vegetative growth in guava cv. Allahabad Safeda.

Conflict of interest

The authors declare that they have no conflict of interest.

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