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Effect of exogenous application of plant growth regulators on vegetative growth and flowering of guava cv. Allahabad Safeda

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ABSTRACT

The experiment was conducted during 2024-25 at Rajasthan College of Agriculture, Udaipur, to evaluate the influence of exogenous application of plant growth regulators on vegetative growth and flowering of the guava cv. Allahabad Safeda. Foliar application of 200 ppm gibberellic acid proved most effective in enhancing the tree height (0.63±0.01 m), tree spread (1.57±0.04 m E-W and 1.25±0.06 m N-S) and canopy volume (10.36±0.34 m³). The increase in stem diameter was greatest with 1500 ppm CCC (1.89±0.01 cm). The total chlorophyll content was greatest (2.32±0.12 mg/g) with 2 ppm brassinosteroids. Gibberellic acid (200 ppm) not only hastened the days to first flowering (27.20±0.32 days) but also accelerated the progression to 50% flowering (53.13±0.81 days). The highest fruit set (78.33±0.26%) and fruit retention (60.33±1.53%) and the highest number of flowers/ shoot (7.55±0.04) were recorded with 200 ppm gibberellic acid. The lowest fruit drop (39.67±1.53%) was also recorded in the treatment 200 ppm gibberellic acid. Overall, 200 ppm gibberellic acid was most effective in promoting vegetative growth and flowering in guava.

Introduction

Guava (*Psidium guajava* L.) a fruit revered for its nutritional richness and delectable flavour, is believed to have originated from the American tropics. *Psidium* is a large genus consisting of as many as 150 species listed in the Kew Index (Pommer and Murakami, 2009). Guava is cultivated in more than 50 countries across tropical and subtropical regions of the world, with major cultivation in India, Brazil, Mexico, Thailand, the USA (Hawaii and Florida), Australia, Philippines, China, Indonesia, Cuba, Java, Malaysia, Bangladesh, Sri Lanka, Myanmar and several African countries. Guava is the fourth most important fruit of India in terms of area and production. India is the world's top guava-producing country, with a growing area of 3.68 lakh ha and 5.48 million tons of production with a productivity of 14.9 MT per hectare (Anonymous, 2024). The top guava producing states in India are Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, Punjab, Bihar and Maharashtra. It can tolerate high temperatures up to 46.1ºC and low temperatures up to -1°C; however,

extreme temperatures during flowering reduce the fruit set percentage and enhance the flower drop and fruit drop percentage.

PGRs have been reported to influence vegetative growth, flowering behaviour, fruit set and yield in guava. However, the response of guava to brassinosteroids, gibberellic acid, growth retardants (CCC) and ethrel with their concentrations varies under different agro-climatic conditions (Fischer and Melgarejo, 2021). Foliar application of PGRs improves flowering behaviour and vegetative growth, increases fruit set and enhances fruit retention, thereby reducing the proportion of flowers and young fruits that are shed prematurely (Lal and Das, 2017; Kumar *et al.*, 2025). Keeping in view, the study was undertaken to identify suitable plant growth regulators and concentrations for improving vegetative growth and flowering behaviour of guava.

Material and Methods

The experiment was conducted during 2024-25 on guava cv. Allahabad Safeda at the Horticulture Farm, Rajasthan College of Agriculture, Udaipur, Rajasthan (24° 34' N latitude and 73° 42' E longitude). Thirteen treatments *viz*., control (T_1), brassinosteroids @ 1 ppm (T_2), brassinosteroids @ 1.5 ppm (T_3), brassinosteroids @ 2 ppm (T_4), gibberellic acid @ 100 ppm (T_5), gibberellic acid @ 150 ppm (T_6), gibberellic acid @ 200 ppm (T_7), CCC @ 500 ppm (T_8), CCC @ 1000 ppm (T_9), CCC @ 1500 ppm (T_{10}), ethrel @ 250 ppm (T_{11}), ethrel @ 500 ppm (T_{12}) and ethrel @ 750 ppm (T_{13}) were applied by foliar spray, one month before flowering in a randomized block design and replicated thrice.

Observations for vegetative growth parameters like change in tree height, change in trunk diameter, change in tree spread (N-S & E-W), leaf chlorophyll content (a, b and total), change in canopy volume and light interception below canopy were observed and for flowering parameters like days taken to first flowering, 50% flowering, number of flowers per shoot, fruit set (%), fruit drop (%) and fruit retention (%) were taken. Trunk diameter was measured as described by Matthews and Mackie (2006). The tree spread was measured in all four directions, East-West and North-South tree spread was measured by metric tape at the time of application of treatment and after harvesting. The canopy volume was calculated by the formula of Westwood and Roberts (1963) and calculated as (m^3) = 4/3 $\pi a^2 b$ where, a = half of the spread and b = half of the height.

Light intensity was measured by 'Luxmeter' (electronic digital Luxmeter) at the crop surface and below the canopy. The reading was taken at the time of application of treatments and after harvesting. The chlorophyll content (chlorophyll 'a', chlorophyll 'b' and total chlorophyll) was estimated according to the method of Hiscox and Israelstom (1979). Recently matured leaf (4^{th} leaf) was collected from the individual trees, and chlorophyll was extracted in 5 ml DMSO from 25 mg fresh leaf tissue by DMSO. In the non-destructive DMSO method, tissues were incubated in a glass beaker for 24 hours at 60°C until the tissues became colourless. Absorbance at 663 and 645 nm was determined by a spectrophotometer. The contents of Chlorophyll 'a' and 'b' were calculated by the following equations:

$$Chlorophyll\ a = \frac{(12.7 \times A_{663}) - (2.69 \times A_{645})}{1000} \times \frac{\text{Volume of DMSO}}{\text{Weight of leaf sample}}$$

$$Chlorophyll\ b = \frac{(22.9 \times A_{645}) - (4.65 \times A_{663})}{1000} \times \frac{\text{Volume of DMSO}}{\text{Weight of leaf sample}}$$

Total chlorophyll was calculated by adding chlorophyll *'a'* to chlorophyll *'b'*.

The total number of flowers was counted on the five randomly selected shoots and the average number of flowers/ shoot was calculated. The per cent fruit set was calculated one month after anthesis from five tagged branches.

$$Fruit\ Set(\%) = \frac{\text{Number of fruits set (Initially)}}{Number\ of\ flowers} \times 100$$

$$Fruit\ Drop\ (\%) = \frac{(\text{Total no. of fruit set} - \text{Total no. of fruits at harvest})}{\text{Total no. of fruits set}} \times 100$$

Fruit retention was noted at the time of final harvesting, when the fruits were fully mature. The total number of fruits harvested was counted and the percentage fruit retention was calculated as follows:

$$Fruit\ Retention\ (\%) = \frac{\text{Total number of fruits retained}}{\text{Total number of fruits initially set}} \times 100$$

Data were subjected to analysis of variance (ANOVA) and treatment means were separated using Tukey's HSD test at 5% LOS.

Results and Discussion

Effect on growth parameters

The foliar application of plant growth regulators significantly influence the growth parameters of

guava (Table 1). The application of gibberellic acid at 200 ppm (T_7) produced the greatest increase in tree height (0.63±0.01 m), marking a 133% improvement over the water-sprayed control. A dose-dependent response was evident within GA_3 treatments, as 150 ppm (T_6) also promoted substantial elongation (0.56±0.02 m), whereas lower concentrations were less effective. CCC @ 1500 ppm (0.19±0.01 m) suppressed vertical growth markedly.

Significant variation in the trunk diameter with the different levels of different plant growth regulators. The increase in trunk diameter varied markedly across PGR treatments, ranging from a minimal 0.46±0.00 cm under gibberellic acid at 200 ppm (T_7) to a maximal 1.89±0.01 cm with CCC at 1500 ppm (T_{10}). This inverse relationship between longitudinal and radial growth reflects the differential allocation of photo-assimilates and hormonal signals under each regulator. Conversely, exogenous gibberellic acid at increasing concentrations prioritized vertical extension. The lowest diameter gain in T_7 confirms that elevated GA_3 levels drive auxin-GA_3 cross-talk toward cell elongation rather than cambial proliferation. Mid-level GA_3 treatments (100-150 ppm) produced moderate trunk thickening, indicating a dose-dependent trade-off between height and girth.

Gibberellic acid at 200 ppm (T_7) produced the widest change in tree spread (1.57±0.04 m in the east-west axis and 1.25±0.06 m north-south), whereas CCC at 1,500 ppm (T_{10}) yielded the narrowest change in tree spread, with just 0.47±0.03 m (E-W) and 0.38±0.04 m (N-S), respectively. Gibberellic acid's ability to break apical dominance and stimulate axillary bud outgrowth explains its dramatic effect on lateral branch extension. GA_3 at 200 ppm in our study more than doubled lateral expansion relative to the control, reflecting a dose-dependent promotion of internodal elongation and branch proliferation.

Gibberellic acid at 200 ppm (T_7) maximized the change in canopy volume (10.36±0.34 m^3), in stark contrast to Ethrel at 750 ppm (T_{13}), which produced the smallest change in canopy volume (3.89±0.12 m^3). These structural changes dramatically altered light penetration. Under T_7, below-canopy light intercepted averaged just 23885 lux, reflecting dense foliage, whereas CCC @ 1500 ppm treated trees (T_{10}) admitted up to 30227 lux beneath the canopy (above-canopy irradiance was 73820 lux for all plots). These results are in conformity with Jain and Dashora (2007), Sharma and Tiwari (2015), Carpenter *et al.* (2019) and Sarolia *et al*. (2019).

Table 1. Effect of exogenous plant growth regulators on growth parameters of guava

Treatment	Change in tree height (m)	Change in trunk diameter (cm)	Change in tree spread (E-W) (m)	Change in tree spread (N-S) (m)	Change in canopy volume (m^3)
Control (T_1)	0.27±0.01^{def}	0.67±0.00^{e}	0.67±0.02^{fgh}	0.53±0.03^{def}	4.53±0.21^{efg}
Brassinosteroids @ 1 ppm (T_2)	0.30±0.02^{de}	0.69±0.01^{e}	0.74±0.01^{f}	0.59±0.03^{de}	5.30±0.09^{de}
Brassinosteroids @ 1.5 ppm (T_3)	0.35±0.01^{cd}	0.93±0.02^{d}	0.87±0.03^{e}	0.70±0.03^{cd}	6.12±0.09^{d}
Brassinosteroids @ 2 ppm (T_4)	0.42±0.01^{bc}	1.21±0.03^{c}	1.04±0.03^{d}	0.83±0.03^{bc}	7.07±0.06^{c}
Gibberellic acid @ 100 ppm (T_5)	0.47±0.03^{b}	0.92±0.00^{d}	1.18±0.02^{c}	0.95±0.03^{b}	8.29±0.10^{b}
Gibberellic acid @ 150 ppm (T_6)	0.56±0.02^{a}	0.54±0.01^{f}	1.41±0.01^{b}	1.13±0.03^{a}	9.52±0.37^{a}
Gibberellic acid @ 200 ppm (T_7)	0.63±0.01^{a}	0.46±0.00^{f}	1.57±0.04^{a}	1.25±0.06^{a}	10.36±0.34^{a}
CCC @ 500 ppm (T_8)	0.26±0.01^{ef}	1.00±0.02^{d}	0.64±0.01^{fgh}	0.52±0.04^{ef}	5.14±0.12^{ef}
CCC @ 1000 ppm (T_9)	0.23±0.02^{ef}	1.37±0.00^{b}	0.59±0.01^{ghi}	0.46±0.03^{ef}	4.45±0.09^{efg}
CCC @ 1500 ppm (T_{10})	0.19±0.01^{f}	1.89±0.01^{a}	0.47±0.03^{i}	0.38±0.04^{f}	4.02±0.10^{g}
Ethrel @ 250 ppm (T_{11})	0.28±0.02^{de}	0.66±0.01^{e}	0.71±0.04^{fg}	0.57±0.03^{de}	5.19±0.07^{ef}
Ethrel @ 500 ppm (T_{12})	0.26±0.01^{ef}	0.92±0.01^{d}	0.64±0.02^{fgh}	0.51±0.03^{ef}	4.35±0.05^{fg}
Ethrel @ 750 ppm (T_{13})	0.23±0.01^{ef}	1.24±0.02^{c}	0.58±0.03^{hi}	0.47±0.04^{ef}	3.89±0.12^{g}

Mean ± SE followed by the same letter is not significantly different at p=0.05 as determined by Tukey's HSD test.

Effect on light interception and chlorophyll content

The data presented in Table 2 indicate that foliar application of plant growth regulators significantly influences light interception and chlorophyll content in guava. Under T_7, below-canopy light intercepted averaged just 23885 lux, reflecting dense foliage, whereas CCC @ 1500 ppm treated trees (T_{10}) admitted up to 30227 lux beneath the canopy (above-canopy irradiance was 73820 lux for all plots). Brar *et al.* (2012) similarly demonstrated that denser guava canopies sharply reduce solar radiation reaching inner foliage, undermining sub-canopy photosynthesis and fruit quality.

The foliar application of brassinosteroids at 2 ppm (T_4) resulted in the highest leaf pigment levels with chlorophyll 'a' (1.50±0.10 mg/ g), chlorophyll 'b' (0.82±0.02 mg/ g) and total chlorophyll (2.32±0.12 mg/ g), whereas ethrel at 750 ppm (T_{13}) produced the lowest values (1.12±0.01, 0.58±0.02 and 1.70±0.01 mg/ g, respectively).

Table 2. Effect of exogenous plant growth regulators on light interception and chlorophyll content

Treatment	Light interception below canopy (Lux)	Chlorophyll 'a' (mg/ g)	Chlorophyll 'b' (mg/ g)	Total chlorophyll (mg/ g)
Control (T_1)	29715^{abc}	1.27 ± 0.04^{bcdef}	0.67 ± 0.01^{bcde}	1.94 ± 0.03^{cdefg}
Brassinosteroids @ 1 ppm (T_2)	28948^{cd}	1.45 ± 0.01^{abc}	0.75 ± 0.05^{abc}	2.20 ± 0.06^{abc}
Brassinosteroids @ 1.5 ppm (T_3)	28124^{d}	1.47 ± 0.02^{ab}	0.79 ± 0.05^{ab}	2.26 ± 0.07^{ab}
Brassinosteroids @ 2 ppm (T_4)	27175^{e}	1.50 ± 0.10^{a}	0.82 ± 0.02^{a}	2.32 ± 0.12^{a}
Gibberellic acid @ 100 ppm (T_5)	25955^{f}	1.37 ± 0.04^{abcde}	0.73 ± 0.01^{abcd}	2.10 ± 0.03^{abcde}
Gibberellic acid @ 150 ppm (T_6)	24722^{g}	1.41 ± 0.07^{abcd}	0.75 ± 0.01^{abcd}	2.16 ± 0.06^{abcd}
Gibberellic acid @ 200 ppm (T_7)	23885^{g}	1.43 ± 0.03^{abcd}	0.78 ± 0.01^{ab}	2.20 ± 0.04^{abc}
CCC @ 500 ppm (T_8)	29110^{bc}	1.32 ± 0.04^{abcdef}	0.72 ± 0.02^{abcd}	2.03 ± 0.06^{bcdef}
CCC @ 1000 ppm (T_9)	29794^{abc}	1.28 ± 0.04^{bcdef}	0.69 ± 0.01^{abcde}	1.98 ± 0.03^{cdef}
CCC @ 1500 ppm (T_{10})	30227^{a}	1.26 ± 0.04^{cdef}	0.67 ± 0.01^{bcde}	1.93 ± 0.03^{defg}
Ethrel @ 250 ppm (T_{11})	29052^{bc}	1.23 ± 0.02^{def}	0.64 ± 0.01^{cde}	1.87 ± 0.02^{efg}
Ethrel @ 500 ppm (T_{12})	29894^{ab}	1.17 ± 0.01^{ef}	0.62 ± 0.03^{de}	1.79 ± 0.02^{fg}
Ethrel @ 750 ppm (T_{13})	30360^{a}	1.12 ± 0.01^{f}	0.58 ± 0.02^{e}	1.70 ± 0.01^{g}

*Light interception above canopy: 73820 lux

Effect on flowering parameters

The data presented in Table 3 demonstrate that foliar application of plant growth regulators significantly affects the flowering parameters of guava. Gibberellic acid at 200 ppm (T_7) not only hastened the days to first flowering (27.20±0.32) but also accelerated its progression, bringing 50% of the flowers into bloom in just 53.13±0.81 days, compared with 42.27±0.86 and 69.17±1.57 days in the untreated control; a reduction of nearly 15 days was seen. In contrast, untreated control (T_1) required the longest duration to reach 50% flowering (69.17±1.57 days), reflecting the natural pace of floral development in the absence of hormonal stimulation. Similar results were found by Jain and Dashora (2007) in guava cv. Sardar.

Gibberellic acid at 200 ppm (T_7) produced the highest flower count, 7.55±0.04 flowers per shoot, whereas the untreated control (T_1) had the fewest, at just 4.84±0.40 flowers per shoot. The foliar gibberellic acid at 200 ppm (T_7) produced the highest fruit set (78.33±0.26%) versus just 59.13±1.44% in the untreated control.

Fruit drop closely mirrored initial set rates. Under GA_3 treatment (T_7), post-set abscission was only 39.67±1.53%, while in the control it was 58.47±1.72%. Gibberellins exert an anti-abscission effect by down-regulating ethylene biosynthesis in the abscission zone and maintaining cell-wall integrity around the pedicel. By contrast, ethrel treatment @ 750 ppm amplifies ethylene release, up-regulating abscission enzymes and provoking 50-55% fruit drop, a phenomenon broadly observed

across pome, stone and tropical fruit studies summarized by Rademacher (2000).

The foliar spray of gibberellic acid at 200 ppm (T_7) showed the highest fruit retention (60.33±1.53%) versus just 41.53±1.72% in the untreated control. Gibberellins enhance sink strength in young ovaries by up-regulating cell-cycle genes and stimulating assimilate partitioning toward developing floral buds. Similar advances have been reported by Sharma and Tiwari (2015) and Agnihotri *et al*. (2016).

Table 3. Effect of exogenous plant growth regulators on flowering parameters of guava

Treatment	Days taken to first flowering (DAS)	Days taken to 50% flowering (DAS)	Number of flowers per shoot	Fruit set (%)	Fruit drop (%)	Fruit retention (%)
Control (T_1)	42.27±0.86^{a}	69.17±1.57^{a}	4.84±0.40^{d}	59.13±1.44^{e}	58.47±1.72^{a}	41.53±1.72^{e}
Brassinosteroids @ 1 ppm (T_2)	39.10±0.62^{ab}	61.43±1.63^{b}	6.36±0.18^{bc}	70.43±1.92^{bc}	47.13±2.10^{de}	52.87±2.11^{ab}
Brassinosteroids @ 1.5 ppm (T_3)	36.63±0.07^{bc}	59.13±0.83^{bc}	6.64±0.09^{abc}	72.23±1.24^{ab}	46.37±1.70^{de}	53.63±1.70^{ab}
Brassinosteroids @ 2 ppm (T_4)	35.13±0.27^{bcd}	57.60±0.40^{bcd}	6.75±0.28^{ab}	73.87±0.83^{ab}	45.80±1.97^{de}	54.20±1.97^{ab}
Gibberellic acid @ 100 ppm (T_5)	32.70±1.68^{cde}	57.27±0.50^{bcd}	6.61±0.27^{abc}	72.07±0.90^{ab}	46.77±2.24^{de}	53.23±2.24^{ab}
Gibberellic acid @ 150 ppm (T_6)	31.10±0.00^{def}	57.03±0.73^{bcd}	6.83±0.12^{ab}	74.10±2.23^{ab}	45.33±1.16^{de}	54.67±2.00^{ab}
Gibberellic acid @ 200 ppm (T_7)	27.20±0.32^{f}	53.13±0.81^{d}	7.55±0.04^{a}	78.33±0.26^{a}	39.67±1.53^{e}	60.33±1.53^{a}
CCC @ 500 ppm (T_8)	37.10±0.79^{b}	61.00±1.88^{b}	5.28±0.19^{d}	67.97±2.28^{bcd}	48.03±0.85^{cd}	51.97±0.85^{bc}
CCC @ 1000 ppm (T_9)	35.13±0.98^{bcd}	58.63±1.18^{bc}	5.58±0.15^{cd}	64.70±2.51^{cde}	51.30±1.32^{abcd}	48.70±1.32^{bcde}
CCC @ 1500 ppm (T_{10})	30.63±0.94^{ef}	56.70±0.26^{bcd}	6.39±0.12^{bc}	63.23±0.50^{de}	56.27±1.05^{ab}	43.73±1.05^{de}
Ethrel @ 250 ppm (T_{11})	35.27±0.70^{bcd}	59.03±0.58^{bc}	6.56±0.07^{abc}	64.00±0.93^{cde}	50.63±1.19^{bcd}	49.37±1.19^{bcd}
Ethrel @ 500 ppm (T_{12})	32.83±0.96^{cde}	57.57±0.53^{bcd}	6.78±0.34^{ab}	63.77±0.67^{cde}	55.27±1.40^{abc}	44.73±1.40^{cde}
Ethrel @ 750 ppm (T_{13})	28.80±0.84^{ef}	55.20±0.38^{cd}	7.38±0.19^{ab}	61.83±1.16^{de}	57.60±1.17^{ab}	42.40±1.18^{de}

Mean ± SE followed by the same letter is not significantly different at p=0.05

Conclusion

The present study concluded that exogenous application of plant growth regulators markedly affects vegetative growth and flowering behaviour in guava. Gibberellic acid at 200 ppm proved most effective, enhancing plant height, canopy development, early flowering, fruit set, and retention while reducing fruit drop. CCC at 1500 ppm restricted vertical growth but promoted stem thickening, contributing to a compact canopy structure. Brassinosteroids at 2 ppm improved chlorophyll content and photosynthetic efficiency, whereas ethrel at 750 ppm negatively influenced growth by increasing fruit drop and chlorophyll degradation. Overall, gibberellic acid at 200 ppm is recommended for improving growth, productivity, and orchard management in guava.

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Conflict of Interest

The authors declare no conflict of interest.

Data Sharing

All relevant data are within the manuscript.

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