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# INFLUENCE OF FOLIAR APPLICATION OF PLANT GROWTH REGULATORS ON FRUIT RETENTION, YIELD AND QUALITY OF MANGO (*MANGIFERA INDICA* L.) CV. AMRAPALI

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**ABSTRACT**

Plant growth regulators (PGRs) are synthetic compounds designed to influence growth, yield, quality, and diverse physiological functions within plants. Hence, the present investigation was conducted to study the effect of foliar application of calcium chloride ($CaCl_2$), naphthalene acetic acid (NAA) and gibberellic acid ($GA_3$) on yield and quality of mango. This study included different combinations of $CaCl_2$ (2%), NAA (40 ppm) and $GA_3$ (20 ppm), and a control was applied one month after the full bloom stage. The findings revealed that spraying of $CaCl_2$ (2%) + NAA (40 ppm) gave significantly higher fruit retention (19.64%) and a higher number of fruits per plant (81.33) at the harvest stage. The physical fruit characters viz., fruit length (10.76 cm), fruit breadth (6.70 cm), fruit volume (198.9 ml), fruit weight (211.5 g), pulp weight (150.3 g), pulp-stone ratio (4.85) and fruit yield per plant (17.03 kg) were improved significantly with combined foliar application of $CaCl_2$ (2%), NAA (40 ppm) and GA3 (20 ppm). Additionally, fruit quality parameters including, TSS (22.13 0 Brix), total sugar (17.16%), reducing sugar (5.90%), ascorbic acid (52.70 mg/100 g pulp), and total carotenoids (2.63 mg/100 g pulp) were also improved significantly with combined PGR application. Conversely, titratable acidity was highest in control (0.23%). In conclusion, combined foliar application $CaCl_2$, NAA and $GA_3$ one month after the full bloom stage significantly enhances mango retention, production and quality.

***Key words :*** NAA, $CaCl_2$, $GA_3$, Yield, Fruit retention, Quality.

## Introduction

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae and the order Sapindales, popularly known as "The King of Fruit" and regarded as the "National fruit of India". Indo-Burma region is considered its centre of origin and it has been under cultivation in the Indian subcontinent for nearly 4000 years ago (Candolle, 1904). In terms of production and consumer attraction mangoes are considered to be the most prominent tropical fruits in the entire world (Kostermans and Bompard, 1993). Mango has social, cultural, religious and medicinal values in India. Unripe fruits are used for pickles, chutneys, powder, flakes, and other culinary preparations while ripe mango fruits are used to make canned mango slices, jam, cereal flakes, squash, nectar, beverage, custard powder, baby food, leather and toffee in addition to desserts. It is very nutritious which contains about 73.0–86.7% moisture, 11.6–24.3% carbohydrate, 4800 IU of vitamin A and 13–39 mg 100 $g^{-1}$ of ascorbic acid, 0.3–1.0% protein. A single fruit of mango, full-filled up to 40% of the daily dietary fibre need of a person (Chandra, 1997).

Worldwide India ranks 1$^{st}$ in terms of area and production having 23.50 lakh hectares of area and production of 207.72 lakh metric tons (MT) with a productivity of 8.8 t $ha^{-1}$ (Anonymous, 2022 (a)). Bihar is one of the major mango-producing states covering an area of 1.60 lakh ha and producing 15.49 lakh MT with a productivity of 9.67 t $ha^{-1}$ (Anonymous, 2022 (b)). In Bihar, commonly cultivated mango varieties are GulabKhas, Bombai, Zardalu, Dushehari, Chausa, Langra and Amrapali. To overcome the problem of yield loss due to biennial and alternate bearing a most popular, prominent hybrid and regular bearer variety, Amrapali was selected for research. Amrapali is a nutritious variety which contains 2.5–3.0 times as much â-carotene than other commercial mango types.

The low productivity of mangoes in India has a negative impact on the economic potential of their production, even though the country has the greatest mango production base globally in terms of the number of varieties planted and the area under cultivation. Jana, Sharangi (1998) stated that fruit drop, alternating bearing, broad tree spacing, malformation and some environmental factors are all responsible for the decrease in mango yield. Several reasons like improper pollination and fertilization, ovule abortion, embryo degeneration, hormone content, high temperatures, insufficient soil moisture, and poor photosynthetic levels are all connected to flower and fruit drooping. (Bains *et al*., 1997; Whiley, 1986). These losses caused by low productivity due to physiological and environmental factors can be minimized through the use of certain plant growth regulators to sustain production throughout the year. Numerous studies on the foliar application of plant growth regulators in various fruit species have been carried out in the past, and the results have demonstrated substantial enhancements in fruit yield and quality. The research done by several researchers (Aly *et al*., 2000; Baghel *et al*., 1987; Bhati and Yadav, 2003) on different fruit crops makes it clear that $GA_3$, NAA and ethephon application contribute to the mango fruit-bearing habit. Despite fruit-dropping, foliar application of plant growth regulators is also helpful in enhancing the fruit retention, yield and post-harvest quality of fruit crops. Nkansah *et al*. (2012) reported that spraying $GA_3$ and NAA @ 25 and 50 ppm concentration, at full bloom stage substantially increased the number of fruits per tree and cluster. It has also been discovered that applying $GA_3$ as a pre-harvest spray can improve the taste, flavour, and organoleptic value of fruits. Sarkar and Ghosh (2005) mentioned in their finding that $GA_3$ when applied as foliar, causes the meristem cells to proliferate and extend, which results in a rise in the weight, volume and length of “Amrapali” mango fruits. Spraying NAA at different concentrations results in increased percentages of fruit set and fruit retention (Oksher *et al*., 1997). It was observed that when mango trees (cv. Amrapali) were sprayed twice with NAA @ 50 ppm, once during the pea stage and another during the marble stage, increased the fruit retention per panicle, number of fruits per plant along with maximum productivity (Vejendla *et al*., 2008). Furthermore, Wahdan *et al*. (2011) also found that two sprayings of (mango cv. Succary Abia) @ 40 and 60 ppm NAA, 2% $CaCl_2$ and 20 and 40 ppm $GA_3$ at full bloom stage increased fruit retention percentage and yield. Thus, after overlooking the importance of plant growth regulators in crop improvement, it is essential to study the effect of different PGRs applications at various concentrations on the mango variety Amrapali. Hence, the present research was proposed to investigate the impact of foliar application of NAA, $CaCl_2$ and $GA_3$ on yield and quality of mango.

## Materials and Methods

### Location, climate, treatment and experiment details

The field experiment was conducted at the horticulture garden, Bihar Agricultural College, Sabour, Bhagalpur during the year 2021–22. The experimental site is situated at the latitude 25$^{o}$ 15' 40" North and longitude 87$^{o}$ 2' 72" East at an altitude of 46 m above mean sea level (MSL) in the Indo-Gangetic plains of India. The climate of Bhagalpur falls under the sub-tropical monsoon which has mild and dry winter with hot summer. The average annual rainfall of Bhagalpur district is 1307 mm. The details of mean monthly weather parameters *viz*., maximum and minimum temperatures, rainfall (mm), relative humidity (%), wind speed (km $h^{-1}$) and sunshine (h) recorded during cropping seasons (2021–22) from Agro-meteorology Observatory, Bihar Agricultural College, Sabour, Bhagalpur.

A 12-year-old mango orchard (cv. Amrapali) was selected for the experiment which was planted with high density planting (HDP) method with a spacing of 3 × 2.2 $m^2$. The experiment was designed in randomized block design (RBD) and replicated thrice having eight treatments including $T_1$ – Control, $T_2$ – $CaCl_2$ (2%), $T_3$ – NAA (40ppm), T4 – GA3(20ppm), $T_5$ – $CaCl_2$ (2%) + NAA (40ppm), $T_6$ – $CaCl_2$ (2%) + $GA_3$ (20ppm), $T_7$ – NAA (40ppm) + $GA_3$ (20ppm), and $T_8$ – NAA (40ppm) + $CaCl_2$ (2%) + $GA_3$ (20ppm). The growth regulators were sprayed once one month after the full bloom stage. The growth regulators namely NAA, $GA_3$ and $CaCl_2$ were sprayed on 12$^{th}$ April in the morning in different combinations and concentrations to study their effect on different yield and quality parameters. For the successful and smooth completion of the research’s ongoing activities healthy, uniform, sturdy and bearing trees were selected. Plant protection measures were carried out to protect the crop from diseases like powdery mildew and anthracnose as well as pests like hoppers and mealy bugs.

**Fruit physical characters and yield parameters analyses**

At harvest randomly five fruits from each plant were selected for fruit physical parameters analysis. Fruit physical parameters include Fruit size (length and breadth), Fruit weight (g), Stone weight (g), Pulp weight (g) and pulp-stone ratio. Fruit size was determined by using a vernier caliper and presented in centimeter. Then Fruit weight (g), stone weight (g) and pulp weight (g) were estimated by using an electronic weighing balance. Fruits pulp and peel have been removed completely and stone weight was measured. Fruit pulp weight was calculated by subtracting the total combined stone and peel weight from the whole fruit weight. After calculation of fruit pulp and stone weight, a pulp-stone ratio was calculated. Fruit volume was calculated by using water displacement method and expressed in ml. The total number of fruits per plant was counted to determine the number of fruits per plant and total fruit weight was measured directly on an electronic weighing balance for the estimation of fruit yield per plant.

**Biochemical analysis**

Treatment-wise randomly ten fruits were selected for biochemical laboratory analysis. The total soluble solid (TSS) was determined with the help of a hand refractometer method and expressed in $^{o}$ Brix. Total sugar (%) was calculated by using the method given by Lane and Eynone (1923). Reducing sugar (%) was estimated by the Shaffer Shomogi method as described by Ranganna (1977). Reducing sugar was subtracted from total sugar and it was designated as non-reducing sugar (%). The titration method as outlined by Rangana (1977) was used to determine titratable acidity (%). Ascorbic acid (mg/100 g pulp) was calculated with the help of the 2, 6-dichlorophenol indophenol dye technique (Jones, Hughes 1983). The total carotenoids were calculated with the help of a simple and rapid method as given by Roy (1973).

**Statistical analysis**

The standard procedure of Randomized Block Design as given by Panse and Sukhatme (1989) was used for statistical analysis to study the effect of application of different growth regulators on yield and quality of mango. Duncan's multiple range tests (DMRT) were used to calculate the least significant differences (LSD) at p = 0.05 for separating the means of different treatments.

## Results and Discussion

**Fruit retention percentage**

The significantly higher fruit retention was noticed with the application of $CaCl_2$ (2%) + NAA (40ppm) – $T_5$ (19.64 %) which follows the report that NAA inhibits the synthesis of abscisic acid and ethylene (Ram 1983). The cause of fruit drop in mango trees seems to be attributed to a deficiency in auxins, gibberellins and cytokinins, along with elevated levels of inhibitors such as abscisic acid and ethylene, as previously noted by Krisanapook *et al*. (2000) and Ram (2000). Nkansah *et al*. (2012) mentioned that spraying 25 mg $L^{-1}$ of NAA at the full bloom stage resulted in enhanced fruit retention in mangoes. Agrawal, Dikshit (2008) also stated that NAA facilitated cell elongation by promoting vacuole enlargement and enhancing cell wall plasticity, thereby leading to an increase in fruit retention. Furthermore, Monselise and Goren (1978) mentioned that the synthesis of hydrolytic enzymes, such as cellulase and polygalacturonase which are responsible for the degradation of cellulose and pectin was prevented with the spraying of auxins which resulted in reduction of fruit drop by maintaining the cells at the zone of abscission. Similarly, calcium has also been shown to promote cell wall rigidity and prevent enzymes such

**Table 1 :** Meteorological parameters recorded during cropping season 2022.

| Cropping period (months) | Meteorological data recorded during cropping season 2022 | | | | | | |
|---|---|---|---|---|---|---|---|
| | $T_{max}$ (°C) | $T_{min}$ (°C) | RH (7:00 AM) | RH (2:00 PM) | Rainfall (mm) | Wind (Km $hr^{-1}$) | Sunshine (hr) |
| January | 20.3 | 10.8 | 95.5 | 65.7 | 7.7 | 7.0 | 2.3 |
| February | 23.9 | 11.3 | 93.6 | 58.8 | 32.4 | 7.3 | 6.3 |
| March | 32.6 | 18.8 | 86.7 | 46.5 | 0.0 | 8.1 | 6.4 |
| April | 36.3 | 22.8 | 84.7 | 53.3 | 2.0 | 15.6 | 5.5 |
| May | 35.4 | 23.5 | 82.3 | 48.9 | 68.6 | 12.5 | 6.5 |
| June | 35.8 | 25.3 | 84.9 | 55.3 | 161.0 | 10.8 | 5.7 |
| July | 36 | 26.1 | 85.0 | 58.7 | 42.6 | 12.1 | 7.7 |
| **Mean/Total** | **31.47** | **19.80** | **87.53** | **55.31** | **314.3** | **10.49** | **5.77** |

**Table 2 :** Effect of plant growth regulators on yield parameters of mango.

| Treatment | Fruit length (cm) | Fruit breadth (cm) | Fruit weight (g) | Peel weight (g) | Stone weight (g) | Pulp weight (g) | Pulp stone ratio | Fruit volume (ml) | Fruit retention at harvest(%) | No. of fruits per plant | Fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | $8.86^{d}$ | $5.90^{b}$ | $177.8^{c}$ | $35.76^{a}$ | $32.63^{a}$ | $109.4^{d}$ | $3.35^{c}$ | $174.7^{b}$ | $14.48^{c}$ | $64.67^{d}$ | $11.49^{b}$ |
| $T_2$ | $9.36^{bcd}$ | $6.20^{ab}$ | $196.6^{ab}$ | $33.56^{abc}$ | $32.50^{a}$ | $130.5^{bc}$ | $4.02^{bc}$ | $189.3^{a}$ | $15.84^{bc}$ | $67.00^{bcd}$ | $13.20^{b}$ |
| $T_3$ | $8.96^{d}$ | $6.30^{ab}$ | $183.7^{bc}$ | $34.10^{ab}$ | $31.80^{a}$ | $117.8^{cd}$ | $3.70^{bc}$ | $187.9^{a}$ | $16.72^{abc}$ | $70.33^{abcd}$ | $12.92^{b}$ |
| $T_4$ | $9.66^{bcd}$ | $6.43^{a}$ | $202.7^{a}$ | $33.33^{abc}$ | $32.50^{a}$ | $136.8^{ab}$ | $4.22^{ab}$ | $196.3^{a}$ | $14.79^{c}$ | $66.66^{cd}$ | $13.49^{b}$ |
| $T_5$ | $9.20^{cd}$ | $6.40^{ab}$ | $198.3^{ab}$ | $33.26^{abc}$ | $32.60^{a}$ | $132.5^{bc}$ | $4.06^{bc}$ | $187.0^{ab}$ | $19.64^{a}$ | $81.33^{a}$ | $16.11^{a}$ |
| $T_6$ | $10.20^{ab}$ | $6.60^{a}$ | $201.5^{a}$ | $31.73^{bc}$ | $31.90^{a}$ | $137.9^{ab}$ | $4.37^{ab}$ | $197.0^{a}$ | $14.96^{c}$ | $79.33^{abc}$ | $15.96^{a}$ |
| $T_7$ | $10.10^{abc}$ | $6.50^{a}$ | $204.4^{a}$ | $32.73^{bc}$ | $31.80^{a}$ | $139.9^{ab}$ | $4.39^{ab}$ | $194.0^{a}$ | $18.27^{abc}$ | $78.33^{abcd}$ | $15.90^{a}$ |
| $T_8$ | $10.76^{a}$ | $6.70^{a}$ | $211.5^{a}$ | $30.96^{c}$ | $30.26^{a}$ | $150.3^{a}$ | $4.85^{a}$ | $198.9^{a}$ | $18.77^{ab}$ | $80.49^{ab}$ | $17.03^{a}$ |
| **LSD(p= 0.05)** | $0.89^{*}$ | $0.45^{*}$ | $11.77^{*}$ | $2.68^{*}$ | $3.13^{ns}$ | $11.53^{*}$ | $0.51^{*}$ | $11.72^{*}$ | $2.30^{*}$ | $10.06^{*}$ | $2.33^{*}$ |
| **SE (m) ±** | 0.29 | 0.14 | 3.84 | 0.86 | 1.03 | 3.76 | 0.17 | 3.83 | 0.75 | 3.25 | 0.71 |

At the p=0.05 level * indicate the significant and $^{ns}$ non-significant differences in the mean of Length of fruit (cm), Breadth of fruit (cm), Fruit weight (g), Peel weight (g), Stone weight (g), Pulp weight (g), Pulp-Stone Ratio, Fruit volume (ml), Number of fruits per plant, Fruit yield per plant (Kg) with different combinations of $CaCl_2$, NAA and $GA_3$; DMRT test represents that values within the columns with different superscript letters are significantly different. Treatments - $T_1$ – Control, $T_2$ – $CaCl_2$ (2%), $T_3$ – NAA (40ppm), $T_4$ – $GA_3$ (20ppm), $T_5$ – $CaCl_2$ (2%) + NAA (40ppm), $T_6$ – $CaCl_2$ (2%) + $GA_3$ (20ppm), $T_7$ – NAA (40ppm) + $GA_3$ (20ppm) and $T_8$ – NAA (40ppm) + $CaCl_2$ (2%) + $GA_3$ (20 ppm).

as polygalacturonase from reaching their active sites, hence delaying the formation of the abscission zone (Suhardi, 1992; Rizk-Alla and Meshreki 2006). Furthermore, spraying of calcium chloride ($CaCl_2$) was found to enhance fruit retention and yield when applied at the fruit growth stage (Rizk-Alla and Meshreki, 2006). The treatment $T_5$ was also found to be on par with the spraying of NAA (40ppm) + $CaCl_2$ (2%) + $GA_3$ (20ppm) – $T_8$ (18.77%) which indicates that $GA_3$ also exerted its effect on fruit retention (Table 2). It was found that gibberellins have been observed to enhance the capacity of organs to function as nutrient sinks and can also boost the biosynthesis of IAA in plant tissues, thereby delaying the formation of the separation layer and consequently promoting fruit retention (Wasfy, 1995). In addition, Ram (1992), Rani and Brahmachari (2004) also observed enhancement in fruit retention in different mango cultivars when they used $GA_3$ for foliar application.

**Number of fruits per plant**

The data regarding the number of fruits is depicted in Table 2. As we used different combinations and concentrations of PGRs, the data for the number of fruits per plant showed variations among the treatments. Significantly (p=0.05) higher number of fruits was recorded with the spraying of $CaCl_2$ (2%) + NAA (40ppm) – $T_5$ (81.33) at full bloom stage which was followed by spraying of NAA (40ppm) + $CaCl_2$ (2%) + $GA_3$ (20ppm) – $T_8$ (80.49), whereas the lowest number value for number of fruits per plant (64.67) was recorded in control ($T_1$). Treatment $T_5$ exerted 25.8% enhancement over the control ($T_1$) whereas $T_8$ registered 24.5% enhancement over the control which clearly indicates that NAA exerted more impact on number of fruit per plant than $GA_3$. Similarly, Gattass *et al.* (2018) also found greater number of fruits per plant under 40 ppm NAA than 40 ppm $GA_3$. Agusti *et al.* (2001) reported that NAA application could increase carbohydrate accumulation and also evidenced that carbohydrate depletion is responsible for diminishing fruit set. Mehouachi *et al.* (1995) mentioned that more amounts of carbohydrates were supplied to the young fruitlet by leaves resulting in higher rates of fruit set. Iglesias *et al.* (2002) found that leaf photosynthesis seems to be essential in determining fruit set in citrus. Hence, the increment in carbohydrate availability to growing mango fruitlets was linked to reduced chances of abscission during fruit growth, resulting in a higher number of fruits at the harvest stage. Kumar *et al.* (2022) in their experiment observed a higher number of fruits in NAA 40 ppm

(70.55%) as compared to $GA_3$ 40 PPM (69.39%). Manivannan *et al*. (2015) also found that the higher number of fruits per plant in case of NAA (50 ppm) was followed by $CaCl_2$ (2%).

**Fruit physical characters and yield attributes**

The fruit's physical characters *viz*., fruit length and breadth, fruit weight, peel weight, stone weight, pulp weight, pulp-stone ratio and fruit volume are enhanced significantly with the application of different PGRs at different combinations and concentrations (Table 2). The findings indicated that significantly (p=0.05) improved value of fruit length (10.76 cm) and breadth (6.70 cm), fruit weight (211.4 g), peel weight (30.96 g), pulp weight (150.2 g), pulp-stone ratio (4.96) and fruit volume (198.9 ml) were registered with the application of NAA (40 ppm) + $CaCl_2$ (2%) + $GA_3$ (20 ppm) ($T_8$), while the lowest value for physical fruit characters was noticed in control ($T_1$). However, stone weight (30.26 g) was found to be non-significant and did not show any assembly with PGRs application. From the data, it is concluded that treatment $T_8$ - NAA (40 ppm) + $CaCl_2$ (2%) + $GA_3$ (20 ppm) recorded 21.4, 13.6. 18.9, 15.5, 37.3, and 13.9 % improvement in case of fruit length, breadth, fruit weight, peel weight, pulp weight and fruit volume compared to control ($T_1$). All these physical fruit characters represent fruit size which is the result of complicated metabolic activities that occur throughout the fruit growth period (Cowan *et al.*, 2001). The main reason for increase in fruit size by application of different PGRs might be due to the substantial enhancement in cell division and cell elongation. Application of PGRs resulted in increased photosynthesis and their translocation towards the fruits during their growth boosted the food storage and ultimately increased the weight and volume of fruit. Foliar application of $GA_3$ resulted in increased cell growth of the mesocarp by boosting sink demand, leading to improved phloem unloading and carbon assimilation metabolism in the fruit (Zhang *et al*., 2007; Brenner and Cheikh, 1995). Ravi, Shanoo (2005) noticed higher fruit weight in guava with foliar application of $GA_3$. Saleem *et al*. (2008) spraying of $GA_3$ improved peel weight in different citrus cultivars. Tripathi *et al*. (2018) registered increased fruit pulp weight with spraying of $GA_3$ @ 50 ppm treatment followed by $CaCl_2$ @ 1.5%. Similar findings regarding fruit size (length, breadth and volume), fruit pulp, peel, fruit and stone weight and pulp-stone ratio were reported by Wahdan *et al*. (2011); Shukla *et al*. (2011); Chandra *et al*. (2015).

**Fruit yield per plant**

The findings presented in Table 2 show that significantly (p=0.05) highest fruit yield per plant (16.42 kg) was recorded with the spraying of NAA (40ppm) + $CaCl_2$ (2%) + $GA_3$ (20ppm) – $T_8$ which was found to be at par with $T_5$, $T_6$, and $T_7$ however, the lowest fruit yield per plant (11.45 kg) was noticed in $T_1$. Treatment $T_8$ – interactive effect of all three PGRs [NAA (40ppm) + $CaCl_2$ (2%) + $GA_3$ (20ppm)] registered 48.2% improvement in fruit yield over the control ($T_1$) whereas $T_5$ – $CaCl_2$ (2%) + NAA (40ppm), $T_6$ – $CaCl_2$ (2%) + $GA_3$ (20ppm), and $T_7$ – NAA (40ppm) + $GA_3$ (20ppm) registered 40.3, 39.0 and 38.4% improvement in fruit yield as compared to control. This increase in fruit yield per plant is absolutely attributable to increased PGR uptake, which improved physiological activities and increased metabolite availability for fruit development and resulted the greater fruit size (length, breadth and volume), weight and better stone weight and pulp-stone ratio which ultimately help in enhancing fruit yield per plant. These results are in harmony with Kumar *et al.* (2022), who mentioned application of 40 ppm $GA_3$ recorded the highest fruit yield per plant. These findings are in agreement with Tripathi *et al*. (2018, 2022); Gattass *et al*. (2018).

**Effect on biochemical parameters**

All biochemical parameters including Total Soluble Solids (TSS, °Brix), sugar percentage (Total sugar, reducing sugar and non-reducing sugar), titrable acidity (%), ascorbic acid (mg/100 g pulp) and carotenoids (mg 100 $g^{-1}$ pulp) were registered enrichment with spraying of various combinations and concentrations of PGRs (Table 3). Results showed that spraying of NAA (40 ppm) + $CaCl_2$ (2%) + $GA_3$ (20 ppm) – $T_8$ at one month after full bloom stage significantly (p=0.05) enhanced the TSS (22.13 ° Brix), total sugar (17.16 %) and reducing sugar (5.90 %) which was followed by Spraying of $CaCl_2$ (2%) + $GA_3$ (20ppm) – $T_6$ while lowest values were noticed in control ($T_1$). Non-reducing sugar was found to be non-significant and showed little variation among the treatments. Treatment $T_8$ enhanced the TSS, total sugar and reducing sugar by 10.3, 21.6 and 30.5% respectively when compared to the control ($T_1$). The enzymatic activities and reactions influenced by calcium which enhanced TSS at the ripening stage which might be due to the conversion of organic compounds into soluble solids (Karemera and Habimana, 2014). The rise in both total soluble solids and total sugar content in fruits could be attributed to the sufficient levels of $GA_3$ and NAA, which enhance auxin content, thereby catalyzing the oxidation process. Gibberellins are recognized to be essential to plants' sugar metabolism in addition Kumar *et al.* (2018) reported that spraying of 2% $CaCl_2$ significantly improved total soluble solids, total sugar and reducing sugar at

**Table 3 :** Effect of plant growth regulators on quality parameters of mango.

| Treatments | TSS ($^0$Brix) | Total sugar (%) | Reducing sugar (%) | Non-reducing sugar (%) | Titratable acidity (%) | Ascorbic acid (mg/ 100g pulp) | Total carotenoids (mg/100 g pulp) |
|---|---|---|---|---|---|---|---|
| $T_1$ | 2010$^c$ | 14.11$^e$ | 4.52$^f$ | 9.59$^b$ | 0.23$^a$ | 36.20$^d$ | 1.79$^g$ |
| $T_2$ | 21.13$^{abc}$ | 15.41$^d$ | 4.89$^e$ | 10.52$^{ab}$ | 0.18$^b$ | 42.36$^c$ | 2.12$^e$ |
| $T_3$ | 20.63$^{bc}$ | 15.62$^d$ | 4.96$^{de}$ | 10.65$^{ab}$ | 0.18$^b$ | 42.03$^c$ | 1.95$^f$ |
| $T_4$ | 21.23$^{abc}$ | 15.68$^{cd}$ | 5.23$^{cd}$ | 10.45$^{ab}$ | 0.17$^{bc}$ | 44.16$^{bc}$ | 2.17$^{de}$ |
| $T_5$ | 21.33$^{abc}$ | 16.67$^{abc}$ | 5.41$^{bc}$ | 11.26$^a$ | 0.18$^b$ | 43.10$^c$ | 2.27$^{cd}$ |
| $T_6$ | 21.86$^{ab}$ | 16.86$^{ab}$ | 5.83$^a$ | 11.03$^{ab}$ | 0.15$^{cd}$ | 48.20$^b$ | 2.49$^b$ |
| $T_7$ | 21.47$^{ab}$ | 15.91$^{bcd}$ | 5.59$^{ab}$ | 10.36$^{ab}$ | 0.16$^{bcd}$ | 46.00$^{bc}$ | 2.32$^c$ |
| $T_8$ | 22.13$^a$ | 17.16$^a$ | 5.90$^a$ | 11.26$^a$ | 0.14$^d$ | 52.70$^a$ | 2.63$^a$ |
| LSD(p=0.05) | 1.20$^*$ | 1.39$^*$ | 0.36$^*$ | 1.41$^{ns}$ | 0.02$^*$ | 3.97$^*$ | 0.13$^*$ |
| SE (m) ± | 0.39 | 0.45 | 0.12 | 0.46 | 0.01 | 1.29 | 0.04 |

At the p=0.05 level * indicate the significant and $^{ns}$ non-significant differences in the mean of TSS ($^0$Brix), Total sugar (%), Reducing sugar (%), non-reducing sugar (%), Titratable acidity (%), Ascorbic acid (mg/100 g pulp), Total carotenoids (mg/100 g pulp) with different combinations of $CaCl_2$, NAA and $GA_3$. DMRT test represents that values within the columns with different superscript letters are significantly different. Treatments - $T_1$ – Control, $T_2$ – $CaCl_2$ (2%), $T_3$ – NAA (40ppm), $T_4$ – $GA_3$ (20ppm), $T_5$ – $CaCl_2$ (2%) + NAA (40ppm), $T_6$ – $CaCl_2$ (2%) + $GA_3$ (20ppm), $T_7$ – NAA (40ppm) + $GA_3$ (20ppm) and $T_8$ – NAA (40ppm) + $CaCl_2$ (2%) + $GA_3$ (20ppm).

harvest and subsequent storage periods in mango. These results follow the findings of Wahdan *et al*. (2011), Dubey *et al*. (2017) and Shukla *et al*. (2011).

Similarly, the foliar application of NAA (40 ppm) + $CaCl_2$ (2%) + $GA_3$ (20 ppm) – $T_8$ at one month after full bloom stage significantly (p=0.05) reduced the titratable acidity (0.14%) however the highest titratable acidity was recorded in control ($T_1$). The data given in Table 3. indicates that the combination of all three PGRs ($T_8$) retarded the titratable acidity percentage by 38.2% over the control whereas the spraying of $CaCl_2$ (2%) + $GA_3$ (20ppm) – $T_6$ decreased acidity by 33.8%, respectively. The decline in titratable acidity results from increased carbohydrate translocation and increased metabolic conversion of acids into sugars, facilitated by the reversal of the glycolytic pathway, utilized either in respiration or both processes. Another possible might be due to early ripening caused by the plant bio-regulator application which breaks down the acid. These findings are in agreement with the results reported by Tripathi *et al*. (2018), Singh and Singh (2015), Chandra *et al*. (2015) and Shukla *et al*. (2011) in aonla cv. Banarasi.

The foliar application of NAA (40 ppm) + $CaCl_2$ (2%) + $GA_3$ (20 ppm) – $T_8$ at one month after full bloom stage significantly (p=0.05) increased ascorbic acid (52.70 mg/ 100 g pulp) which was followed by foliar application of $CaCl_2$ (2%) + $GA_3$ (20ppm) – $T_6$ while the lowest values of ascorbic acid (36.20 mg/100 g pulp) was recorded in control ($T_1$) (Table 3). The combined application of three PGRs ($T_8$) increased ascorbic acid by 45.6% compared to control which was higher than the other combination of PGRs. The increased level of ascorbic acid with the combined application of PGRs could be due to the low rate of oxidation and continuous production of ascorbic acid's precursor, glucose-6-phosphate, which occurs during the conversion of starch into other sugars. Similar results were reported by Tripathi *et al*. (2019) and Mourya *et al*. (2020) in mango, Shukla *et al*. (2011) in aonla and Dubey *et al*. (2017) in strawberry.

A similar trend was observed in case of carotenoids (Table 3) as foliar application NAA (40 ppm) + $CaCl_2$ (2%) + $GA_3$ (20 ppm) – $T_8$ at one month after full bloom stage significantly (p=0.05) increased carotenoids (2.63 mg/100 g pulp) of mango fruit and followed by $CaCl_2$ (2%) + $GA_3$ (20ppm) – $T_{6,}$ while the lowest value of carotenoids (1.79 mg/100 g pulp) was noticed in control ($T_1$). Treatments $T_8$ and $T_6$ increased the content of carotenoids by 46.7 and 38.8% as compared to the control respectively. It means that combined application of all three PGRs registered the highest value of carotenoids than the other PGR combination. Mondal *et al*. (2015) also mentioned a substantial increment in carotenoids content with the combined application of $GA_3$ and NAA along with Urea in mango.

## Conclusion

It is clear from the above investigation that the foliar application of $CaCl_2$ (2%) + NAA (40ppm) significantly enhanced the number of fruits per plant and reduced the fruit drop by increasing fruit retention at harvest. However, the fruit's physical characteristics *viz*., fruit length and breadth, fruit weight, peel weight, stone weight, pulp weight, pulp-stone ratio and fruit volume are enhanced significantly with the combined application of PGRs *i.e*. NAA (40ppm) + $CaCl_2$ (2%) + $GA_3$ (20ppm). Thus, it can be recommended to the mango growers of the nearby sabour area to achieve maximum returns.

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## References


Agrawal, S. and Dikshit, S.N. (2008). Studies on the effect of plant growth regulators on growth and yield of sapota (*Achras sapota* L.) cv. cricket ball. *Indian J. Agric. Res.* **42**, 207–11.

Agusti, M., Zaragoza S., Iglesias D.J., Almela V., Primo-Millo E. and Talon M. (2001). The synthetic auxin 3,5,6-TPA stimulates carbohydrate accumulation and growth in citrus fruit. *Plant Growth Regulation*, **66**, 1–7.

Aly, M.A., Bacha M.A.A., Al-Queeb R.S. and Abdul-Rahman A.O. (2000). *J. Saudi Soc. Agric. Sci*. **12**, 1420.

Anonymous (2020-a, b). Agricultural Statistics at a Glance. 2022. Economics & Statistics Division, Department of Agriculture & Farmers Welfare. www.agricoop.nic.in & http://desagri.gov.in

Baghel, B.S., Sharma R.K. and Nain P.K.K. (1987). *Progress. Hortic*., **19**, 200.

Bains, K.S., Bajwa G.S. and Singh Z. (1997). Abscission of mango fruitlets. I. In relation to endogenous concentrations of IAA, GA and ABA in pedicels and fruitlets. *Fruits,* **52**, 159–65.

Bhati, B.S. and Yadav P.K. (2003). *J. Hortic. Sci.,* **32**, 32.

Brenner, M.L. and Cheikh N. (1995). The role of hormones in photosynthate partitioning and seed filling. Plant hormones: Physiology, biochemistry and molecular biology. Kluwer Academic Publishers, Dordrecht, Netherlands, **9**:145

Candolle, A.D. (1904). *Origin of cultivated plants*. Kegan Paul, Trench, Trulener and Co. Ltd., London, UK.

Chandra, A. (1997). Production and Postharvest Technology of Fruits. NBS publishers and Distributors, Bikaner, India.

Chandra, R., Rawat M., Singh S. and Singh K.K. (2015). Effect of foliar application of various growth regulators on yield and quality of aonla (*Emblica officinalis* Gaertn.) cv. NA-7. *J. Trop. Agric.*, **33**, 2123–27.

Cowan, A.K., Cripps R.F., Richings E.W. and Taylor N.J. (2001). Fruit size: towards an understanding of the metabolic control of fruit growth using avocado as a model system. *Physiol. Plant.,* **111**, 127–136.

Dubey, Vishal, Meena M.L. and Tripathi V.K. (2017). Effect of plant bio-regulators and micronutrient on vegetative growth, yield and quality of strawberry cv. Chandler. *Progress. Res.*, **12**, 330–332.

Gattass, H.R., Essa A.A., Hend A.M. and Safaa M. (2018). Effect of application of some growth regulators and $CaCl_2$ on fruit drop, yield and fruit quality of Keitt mango trees. *Assiut J. Agri. Sci.,* **49**, 79–95.

Iglesias, D.J., Lliso I., Tadeo F.R. and Talon M. (2002). Regulation of photosynthesis through source: sink imbalance in citrus is mediated by carbohydrate content in leaves. *Physiol. Plant.*, **116**, 563–572. doi: 10.1034/j.1399-3054.2002.1160416.x

Jana, A. and Sharangi A.B. (1998). Fruit drop in different varieties of mango. *Environ. and Ecol.,* **16**, 127–131.

Jones, E. and Hughes R.E. (1983). Foliar ascorbic acid in some angiosperms. *Phytochem.*, **22**, 2493–2499.

Karemera, N.U. and Habimana S. (2014). Effect of preharvest calcium chloride on postharvest behaviour of mango fruits (*Mangifera indica* L.) cv. Alphonso. *Univers. J. Agric. Res.*, **2**, 119–125.

Kostermans, A.J.G.H. and Bompard J.M. (1993). The mangoes-their botany, nomenclature, horticulture and utilization. IBPGR Academic Press, London, UK.

Krisanapook, K., Phavaphutanon L., Kaewladdakorn and Pickakum A. (2000). Studies on fruit growth, levels of GA-like substances and CK-like substances in fruits of mango cv. Khiew Sawoey. *Acta Hortic.*, **509**, 694–704.

Kumar, P., Kumar D., Gangwar V., Pal O., Veersain Kumar A. and Dwivedi A.K. (2022). Effect of NAA and $GA_3$ on Fruit Yield and Yield attributary Traits in Phalsa (*Grewia subinaequalis* D.C.) cv. Sharbati. *Int. J. Environ. Clim. Change*, **12**, 2010–2015. DOI: 10.9734/IJECC/2022/v12i1131190.

Kumar Rajeev, Tripathi V.K., Tomar Saurabh and Chaudhary Mahendra (2018). Effect of best plant bioregulators and micronutrient for achieving higher yield and quality of mango (*Mangifera indica* L.) Fruits cv. Amrapali. *J. Plant Dev. Sci.,* **10**, 599–604.

Lane, J.H. and Eynon L. (1923). Determination of reducing sugars by Fehling's solution with methylene blue indicator. *Soc. Chem. Ind.*, **42**, 32–63.

Mandal, B.K., Rani R. and Ray R.N. (2015). Effect of Foliar Spray of Urea and Growth Regulators on Marketable Yield and Quality of Mango Cv. "Amrapali". *Int. J. Agric. Sci.*, **7**, 554–558.

Manivannan, M.I., Irulandi S. and Shoba K.T. (2015). Studies on the effect of pre-harvest application of plant growth regulators and chemicals on yield and quality of guava (*Psidium guajava* L.) cv. L.-49. *Int. J. Agric. Sci.*, **11**, 138–40. DOI: 10.15740/HAS/IJAS/11.1/138–140.

Maurya, P.K., Tripathi V.K. and Gupta Shubham (2020). Effect of pre-harvest application of $GA_3$, Naphthalene acetic acid and borax on fruit drop, yield and quality of Mango cv. Amrapali. *J. Pharmacogn Phytochem.*, **9**, 2123–27. DOI: https://doi.org/10.22271/phyto.2020.v9.i6ae.13275.

Mehouachi, J., Serna D., Zaragoza S., Agusti M., Talon M. and Primo-Millo E. (1995). Defoliation increases fruit abscission and reduces carbohydrate levels in developing fruits and woody tissues of *Citrus unshiu*. *Plant Sci.*, **107**, 189–197. doi: 10.1016/0168-9452(95)04111-7.

Monselise, S.P. and Goren R. (1978). The role of internal factors and exogenous control in flowering, peel growth and abscission in citrus. *Hortic. Sci.*, **13**, 134–139.

Nkansah, G.O., Ofosu-Anim J. and Mawuli A. (2012). Gibberellic acid and naphthalene acetic acid affect fruit retention, yield and quality of Keitt mangoes in the coastal savanna ecological zone of Ghana. *Americ. J. Plant Physiol.*, **7**, 243–251. doi: 10.3923/ajpp.2012.243.251.

Oksher, A.K., Ramachandran C. and Pyhodath J.S. (1997). Effect of planofix on fruit set in mango. *Agric. Res. J.*, **17**, 105.

Panse, V.C. and Sukhatme P.V. (1989). Statistical methods for Agricultural workers. Indian Council of Agricultural Research, New Delhi, pp. 199–210.

Ram, S. (1983). Hormonal control of fruit growth and fruit drop in mango cv. 'Dusehri'. *Acta Hortic.*, **134**, 169–178.

Ram, S. (1992). Naturally occurring hormones of mango and their role in growth and drop of fruit. *Acta Hortic.*, **321**, 400–411.

Ram, S. (2000). Hormonal control of fruit growth and fruit drop in mango cv. Dashehari. *Acta Hortc.*, **509**, 137–149.

Ranganna, S. (1977). *Manual of Analysis of Fruit and Vegetable Products*. 2nd Edition, Tata Mc Graw Hill Publishing Company Ltd., New Delhi.

Rani, R. and Brahmachari V.S. (2004). Effect of growth substances and calcium compounds on fruit retention, growth and yield of 'Amrapali' mango. *Orissa J. Hortic.*, **32**, 15–17.

Ravi, K. and Shanoo B. (2005). Effect of pre-harvest application of plant growth regulators ($GA_3$, NAA and CCC) on post-harvest quality of guava (*Psidium guajava* L.) cv. 'Sardar'. *Indian J. Res.*, **4**, 88–95.

Rizk-Alla, M.S. and Meshreki A.M. (2006). Effect of pre-harvest application of $GA_3$, potassium and glucose on fruit quality and storability of Crimson Seedless cultivar. *Egypt. J. Appl. Sci.*, **20**, 210–238.

Roy, S.K. (1973). Simple and rapid method for estimation of total carotenoid pigments in mango. *J. Food Sci. Technol.*, Tokyo.

Saleem, B.A., Malik A.U., Pervez M.A. and Khan A.S. (2008). Growth regulators application affects vegetative and reproductive behavior of blood red sweet orange. *Pak. J. Bot.*, **40**, 2115–2125.

Sarkar, S. and Ghosh B. (2005). Effect of growth regulators on biochemical composition of mango cv. "Amrapali". *Environ. and Ecol.*, **23** (Special 2), 379–80.

Shukla, H.S., Kumar V. and Tripathi V.K. (2011). Effect of gibberellic acid and boron on development and quality of aonla fruits 'Banarasi'. *Acta Hortic.*, **890**, 375–380.

Singh, A. and Singh H.K. (2015). Application of plant growth regulators to improve fruit yield and quality in Indian gooseberry (*Emblica officinalis* Gaertn.). *J. Agri. Res.*, **2**, 20–23.

Suhardi, Y. (1992). Ripening retardation of Arumanis mango. *ASEAN Food J.*, **7**, 207–208.

Tripathi, V.K., Pandey S.S., Kumar A., Dubey V. and Tiwari P. (2018). Influence of foliar application of gibberellic acid, calcium and boron on fruit drop, yield and quality attributes of aonla (*Emblica officinalis*) cv. NA 7. *Indian J. Agric. Sci.*, **88**, 1784–1788. DOI: 10.56093/ijas.v88i11.84931.

Tripathi, V.K., Singh A., Bhadauria A.S. and Gupta S. (2019). Influence of $GA_3$ and Naphthalene Acetic acid alone and in combination on fruit drop, yield and quality of mango cv. Amrapali. *Progress. Res.*, **14**, 10–13.

Vejendla, V., Maity P.K. and Banik B.C. (2008). Effect of chemicals and growth regulators on fruit retention, yield and quality of mango cv. Amrapali. *J. Crop and Weed.*, **4**, 45–46.

Wahdan, M.T., Habib S.E., Bassal M.A. and Qaoud E.M. (2011). Effect of some chemicals on growth, fruiting, yield and fruit quality of" Succary Abiad" mango cv. *Amer. J. Sci.*, **7**, 651–658.

Wasfy, E.H. (1995). *Growth Regulators and Flowering*. Academie Bookshop, Egypt: 560–80.

Whiley, A.W. (1986). Crop management review. Proceeding first Australian mango research workshop. CSIRO, Australia, Melbourne. pp: 186–95.

Zhang, C., Tanabe K., Tani H., Nakajima H., Mori M., Itai A. and Sakuno E. (2007). Biologically active gibberellins and abscisic acid in fruit of two late-maturing Japanese pear cultivars with contrasting fruit size. *J. Amer. Soc. Hortic. Sci.*, **132**, 452–458.